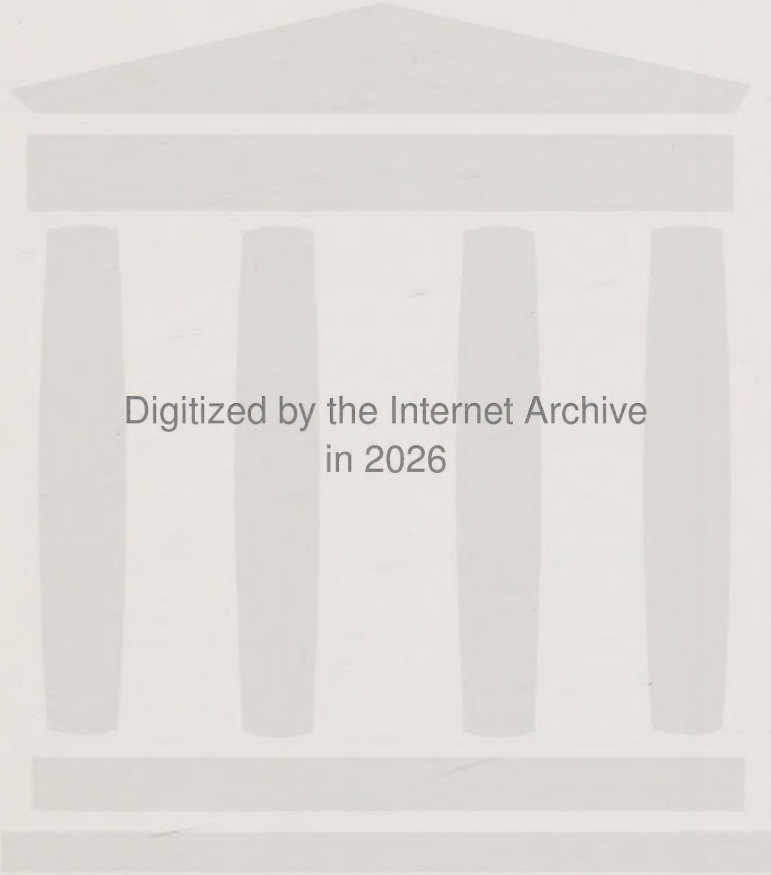


**AUTOMOBILE SHOP
MATHEMATICS**

HARPER



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MATHEMATICS TEXTS

By

HERBERT DRUERY HARPER, PH.D.



General Shop Mathematics

All the material necessary for a course in shop mathematics is presented so clearly and so thoroughly that it makes mathematics a tool of practical, every-day usefulness.

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Essential mathematical instruction is given in problems related to plumbing installation, heat and temperature.

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The mathematical implications of the common processes and materials of the printing trade are arranged in an educational sequence.



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AUTOMOBILE SHOP MATHEMATICS

BY

HERBERT DRUERY HARPER

*Woodrow Wilson Vocational High School
New York City*



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PREFACE

This book is strictly limited in scope to the needs of the student of automobile repair and construction. The subjects covered in this work were chosen with the idea of giving the student added information relating to the automobile, while he is learning mathematical processes. The work is so arranged that certain parts may be omitted if desired.

The use of formulas without explanation of their derivation has been made so that the book would not be too technical for students in vocational, continuation and junior high schools. A knowledge of the fundamentals of arithmetic is therefore the only prerequisite. The author's "General Shop Mathematics," published by D. Van Nostrand Company, furnishes a good foundation for this work.

The blue prints should help to stimulate the interest of the student, for instead of mere mechanical drill on abstract problems he finds himself in the atmosphere of the shop, all the problems being of a practical nature. The arrangement of the pages, with the explanation and problems facing the blue prints, makes for greater efficiency in learning. The vocational intelligence of the student should be enlarged by their use and his interest in shop work should be carried over into academic subjects.

H. D. H.

NEW YORK,
October 1, 1928

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AUTOMOBILE SHOP MATHEMATICS

CHAPTER I

SPEED RATIOS

REVOLUTIONS PER MINUTE

It is desirable and sometimes necessary for an auto-mechanic to know the speed of the different elements of an engine and of the garage equipment. A few simple rules enable the student to find the speed of any pulley or gear. Briefly stated, these are:

1. *Diameters of pulleys are inversely proportional to their speed.*

Expressed as a proportion

$$\frac{\text{Number of R.P.M. of driven pulley}}{\text{Number of R.P.M. of driving pulley}} = \frac{\text{Diameter of driving pulley}}{\text{Diameter of driven pulley}}.$$

2. *The speed of gears is inversely proportional to their number of teeth.*

Expressed as a proportion

$$\frac{\text{Number of R.P.M. of driven gear}}{\text{Number of R.P.M. of driving gear}} = \frac{\text{Number of teeth on driving gear}}{\text{Number of teeth on driven gear}}.$$

When applied to pulley trains or gear trains, these become:

3.
$$\frac{\text{R.P.M. of last driven pulley}}{\text{R.P.M. of first driving pulley}} = \frac{\text{Product of diameters of all driving pulleys}}{\text{Product of diameters of all driven pulleys}}.$$
4.
$$\frac{\text{R.P.M. of last driven gear}}{\text{R.P.M. of first driving gear}} = \frac{\text{Product of number of teeth of driving gears}}{\text{Product of number of teeth of driven gears}}.$$

Note: Ratio and Proportion is explained in Chapter III of "General Shop Mathematics."

SPEED RATIOS

REVOLUTIONS PER MINUTE

ILLUSTRATIVE PROBLEM

In fig. 1, page 3, the pulley on the crankshaft which drives the fan is 4" in diameter and the diameter of the fan pulley is 2". Find the speed of the fan when the crankshaft rotates at 1000 R.P.M.

Rule.—*R.P.M. of last driven pulley: R.P.M. of first driving pulley = Diameter of driving pulley: diameter of driven pulley.*

$$X : 1000 = 4 : 2,$$

2

$$X = \frac{1000 \times 4}{2} = 2000.$$

Therefore the fan revolves at 2000 revolutions per minute.

EXERCISES

Find the R.P.M. of the fan in each of the following cases:

	Engine Speed	Diameter of Crankshaft Pulley	Diameter of Fan Pulley
1.	1800	3½"	2¼"
2.	1200	3½"	1½"
3.	1500	3½"	1½"

ILLUSTRATIVE PROBLEM

In fig. 2, the crankshaft gear has 25 teeth and the gear on the cam shaft 50 teeth. If the crankshaft runs at 1800 R.P.M., find the speed of the cam shaft.

Rule.—*R.P.M. of last driven gear : R.P.M. of first driving gear = number of teeth on driving gear : number of teeth on driven gear.*

$$X : 1800 = 25 : 50,$$

900

$$X = \frac{1800 \times 25}{50} = 900.$$

Therefore the cam shaft revolves at 900 revolutions per minute.

EXERCISES

In the following cases find the R.P.M. of the cam shaft:

	Engine Speed	Smaller Timer Gear	Larger Timer Gear
1.	1000	22	46
2.	1250	26	50
3.	1725	24	52



FIG. 1

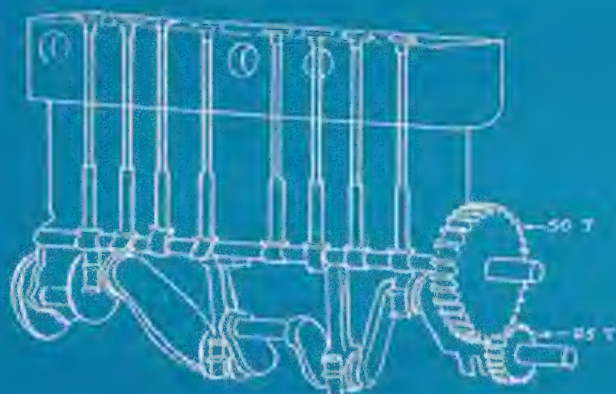


FIG. 2

SPEED RATIOS

REVOLUTIONS PER MINUTE

ILLUSTRATIVE PROBLEM

If the motor in the blue print, page 5, has a speed of 800 R.P.M., find the speed of the pulley on the air compressor.

Rule.—

$$\frac{\text{R.P.M. of last driven pulley}}{\text{R.P.M. of first driving pulley}} = \frac{\text{Product of diameters of all driving pulleys}}{\text{Product of diameters of all driven pulleys}}$$

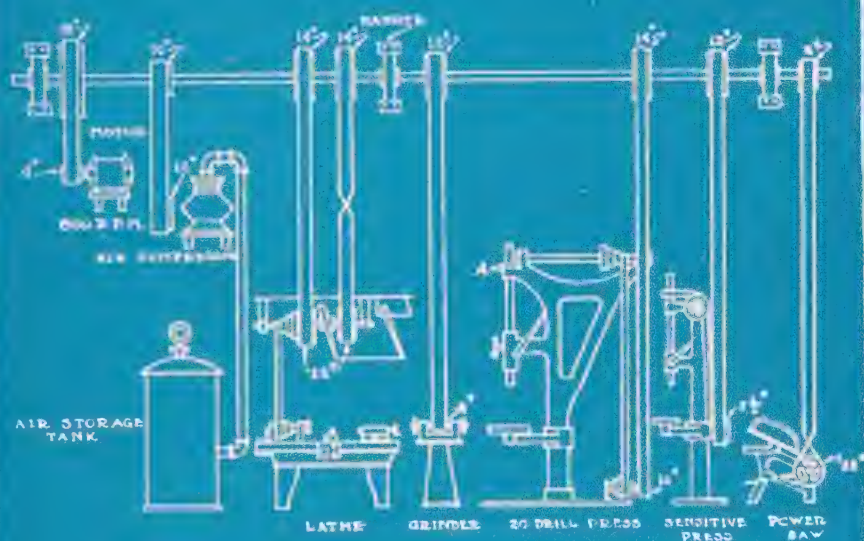
$$X : 800 = (4 \times 10) : (18 \times 12),$$

$$X = \frac{800 \times \cancel{4} \times \overset{5}{\cancel{10}}}{\underset{9}{\cancel{18}} \times \underset{3}{\cancel{12}}} = \frac{4000}{27} = 148.$$

Therefore the compressor pulley revolves at 148 revolutions per minute.

EXERCISES

1. Find the R.P.M. of the lathe countershaft.
2. The cone pulley diameters on the countershaft are 10'', 8½'', 7'' and 5½'' and the corresponding lathe cone pulleys are connected to it in reverse order, 5½'', 7'', 8½'' and 10''. Find the R.P.M. of each diameter.
3. Find the R.P.M. of the grinder.
4. Find the R.P.M. of the 10'' pulley on the 20'' drill press.
5. If the bevel gear ratio is 2 to 1 (that is, gear A has twice the number of teeth as the mating gear) on the 20'' drill press spindle and the cone pulley diameters are 5'', 6'' and 7'' respectively, find the R.P.M. of the drill for each step.
6. Find the R.P.M. of the sensitive drill press.
7. Find the R.P.M. of the power-saw.
8. What size driving pulley would have to be placed on the line shaft in order to increase the speed of the air compressor to 300 R.P.M.?
9. What size pulley would replace the 14'' pulley on the line shaft so that the lathe countershaft speed would be increased 50 R.P.M.?



SPEED RATIOS**REVOLUTIONS PER MINUTE**

The blue print on page 7 shows a three-speed selective type of transmission which is the type usually used in a passenger automobile. Notice that it is not necessary for the sliding gear to pass through another gear.

ILLUSTRATIVE PROBLEM

Find the speed of the drive shaft of the three-speed selective transmission when the first speed gears of 17 T and 31 T are engaged, if the motor is revolving at 1000 R.P.M.

Rule.—

$$\frac{\text{R.P.M. of last driven gear}}{\text{R.P.M. of first driving gear}} = \frac{\text{Product of teeth on driving gears}}{\text{Product of teeth on driven gears}}$$

$$X : 1000 = (16 \times 17) : (32 \times 31),$$

$$X = \frac{1000 \times 16 \times 17}{32 \times 31} = \frac{8500}{31} = 274.$$

Therefore the drive shaft rotates at 274 R.P.M. in low speed.

EXERCISES

Find the R.P.M. of the drive shaft in each of the following cases:

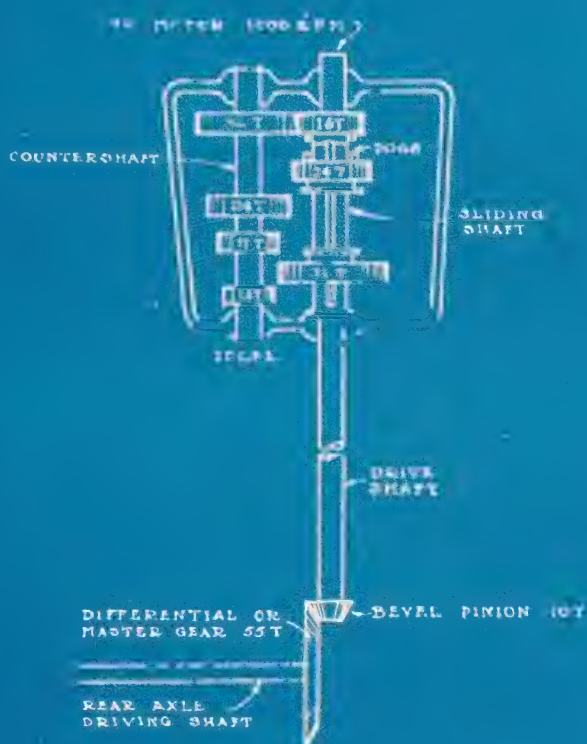
1. When the 2d speed gears are engaged. The 24 T gears are the second speed gears.
2. When the 3d speed gears are engaged. The projectors, called dogs, on the 16 T and 24 T are engaged at third speed. Can you tell the speed by inspection?
3. When the reverse speed gears are engaged. The 13 T and 31 T are the gears used in reverse.

Find the R.P.M. of the rear axle driving shaft in each of the following cases:

4. When the 1st speed gears are engaged.

Note: In these problems the 10 T bevel pinion and 55 T master gear must be considered.

5. When the 2d speed gears are engaged.
6. When the 3d speed gears are engaged.
7. When the reverse gears are engaged.
8. When running at full speed the engine revolves 2200 R.P.M. Find each speed of the rear axle driving shaft.



SPEED RATIOS

REVOLUTIONS PER MINUTE

REVIEW EXERCISES

1. In fig. 1, find the R.P.M. of the cam shaft gear.

Note: An idler gear does not affect the speed of the driven gear.

2. In fig. 1, find the R.P.M. of the magneto gear.

3. When the engine speed is 1400 R.P.M. and the crankshaft pulley diameter is $3\frac{9}{16}$ " and the fan pulley diameter is $2\frac{1}{32}$ ", find the R.P.M. of the fan pulley.

4. In fig. 2, find the R.P.M. of the magneto gear.

5. Find the diameter of a fan pulley that is belted to a $4\frac{1}{16}$ " crankshaft pulley so that the fan will revolve at 2000 R.P.M. when the engine is running at 1500 R.P.M.

6. In fig. 2, find the R.P.M. of the cam shaft gear.

7. If the engine in fig. 3 is running at 1800 R.P.M., find the speed of the fan.

8. In ex. 7, find the speed of the fan if the fan pulley is changed to $2\frac{1}{8}$ ".

9. A 5" pulley on a countershaft drives a 24" pulley on a power-saw. What should be the speed of the countershaft to drive the back saw at 30 R.P.M.?

10. In ex. 9, what size pulley is needed on the power-saw to increase speed to 40 R.P.M.?

11. In fig. 4, find the speed the motor must revolve to give 200 R.P.M. to the flywheel on the engine.

Find the R.P.M. of the engine fan in each of the following cases:

	Engine Speed	Diameter of Shaft Pulley	Diameter of Fan Pulley
12.	1900	$3\frac{1}{4}$ "	$2\frac{1}{8}$ "
13.	2200	$3\frac{9}{16}$ "	$2\frac{1}{16}$ "



FIG. 1



FIG. 2

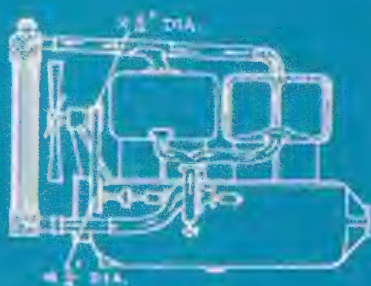


FIG. 3

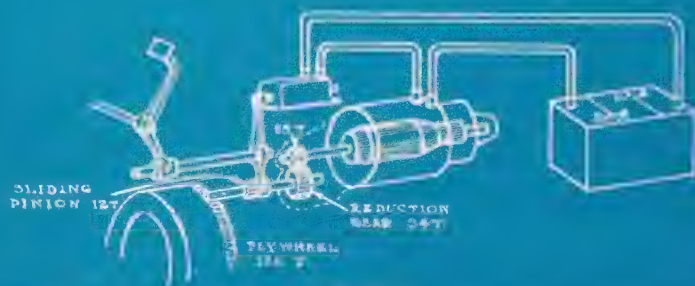


FIG. 4

SPEED RATIOS

REAR AXLE RATIOS

The blue print on page 11 shows the method of connecting a transmission case to the rear axle. The transmission is provided so that the speed of the automobile may be varied. The one shown is a three-speed selective, that is, no gear passes through another when changing speeds. The number of revolutions made by the engine to one of the wheels is not the same for all makes of automobiles, because different-sized gears are used, thereby giving a different rear axle ratio, transmission ratio and total gear reduction.

REAR AXLE RATIO

Rear axle ratio refers to the number of revolutions the rear axle turns to one revolution of the propeller or drive shaft.

Rule.—To find the rear axle ratio, divide the number of teeth on the differential gear by the number of teeth on the drive pinion.

$$\frac{\text{Differential gear } 74 \text{ T}}{\text{Drive pinion } 17 \text{ T}} = 4.353.$$

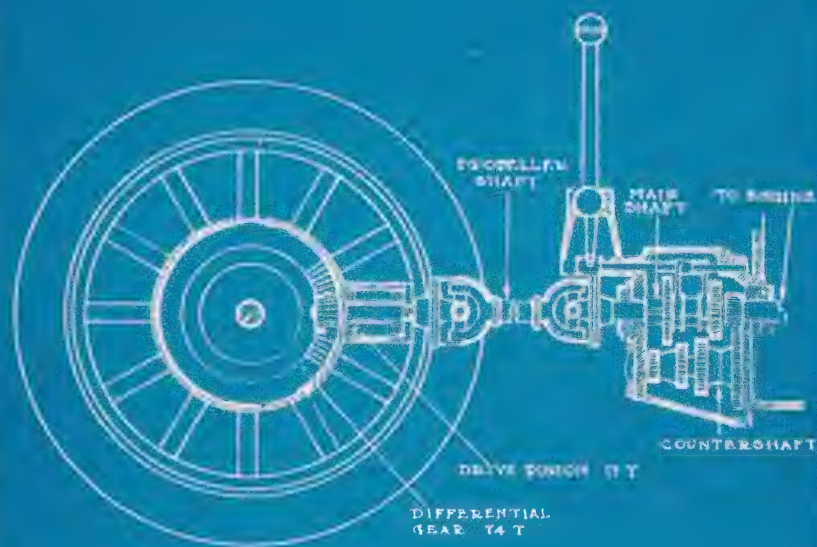
Therefore the propeller shaft makes 4.353 R.P.M. to 1 R.P.M. of the axle, or, written as a ratio, 4.353 : 1.

EXERCISES

Find the rear axle ratios in each of the following cases.

	Differential Gear	Drive Pinion		Differential Gear	Drive Pinion
1.	71 T	16 T	4.	77 T	18 T
2.	83 T	19 T	5.	68 T	15 T
3.	76 T	17 T	6.	69 T	14 T

7. One car has a 75 T differential gear with a 19 T drive pinion while another has a 70 T differential gear with a 13 T drive pinion. Which car has the largest rear axle ratio?



SPEED RATIOS

TRANSMISSION RATIOS

Transmission ratio refers to the ratio between the engine shaft and the propeller shaft.

Rule.—To find transmission ratio, multiply all of the driven gears together and divide the product of the driven gears by the product of the driving gears.

ILLUSTRATIVE PROBLEM

In fig. 1 on page 13, find the transmission ratio for the first speed.

$$\text{Transmission Ratio} = \frac{\overset{2}{\cancel{34}} \times 31}{\cancel{17} \times \cancel{26}} = \frac{31}{10} = 3.1.$$

Therefore, on 1st speed, the engine crankshaft revolves 3.1 times to one of the propeller shaft.

The transmission ratio for 2d speed is found in like manner. Third or high speed ratio is always 1 to 1; that is, the engine crankshaft revolves once to one revolution of the propeller shaft.

EXERCISES

1. Find the transmission ratio in fig. 2.
2. If in fig. 1 the driving gears had 15 and 19 teeth and the driven gears 29 and 33 teeth, find the transmission ratio.
3. If in fig. 2 the driving gears had 17 and 26 teeth and the driven gears 28 and 36 teeth, find the transmission ratio.
4. Draw two parallel shafts and place on them the gears necessary for a three-speed selective transmission.

Note: The sum of the teeth of the gears in mesh must always be the same total except when gears are in reverse. Notice in the third speed drawing in the blue print that the total is 51.

5. In ex. 4, find the transmission ratios for 1st and 2d speeds.



SPEED RATIOS

TOTAL GEAR REDUCTION

Total gear reduction refers to the number of revolutions the crankshaft makes to one revolution of the axle shaft.

Rule.—To find the total gear reduction, multiply the transmission ratio by the rear axle ratio.

ILLUSTRATIVE PROBLEM

Find the total gear reduction when the transmission gears are in first speed, page 13.

$$3.1 \text{ transmission ratio} \times 4.353 \text{ rear axle ratio} = 13.494.$$

Therefore the crankshaft turns over 13.494 times while the rear axle revolves once.

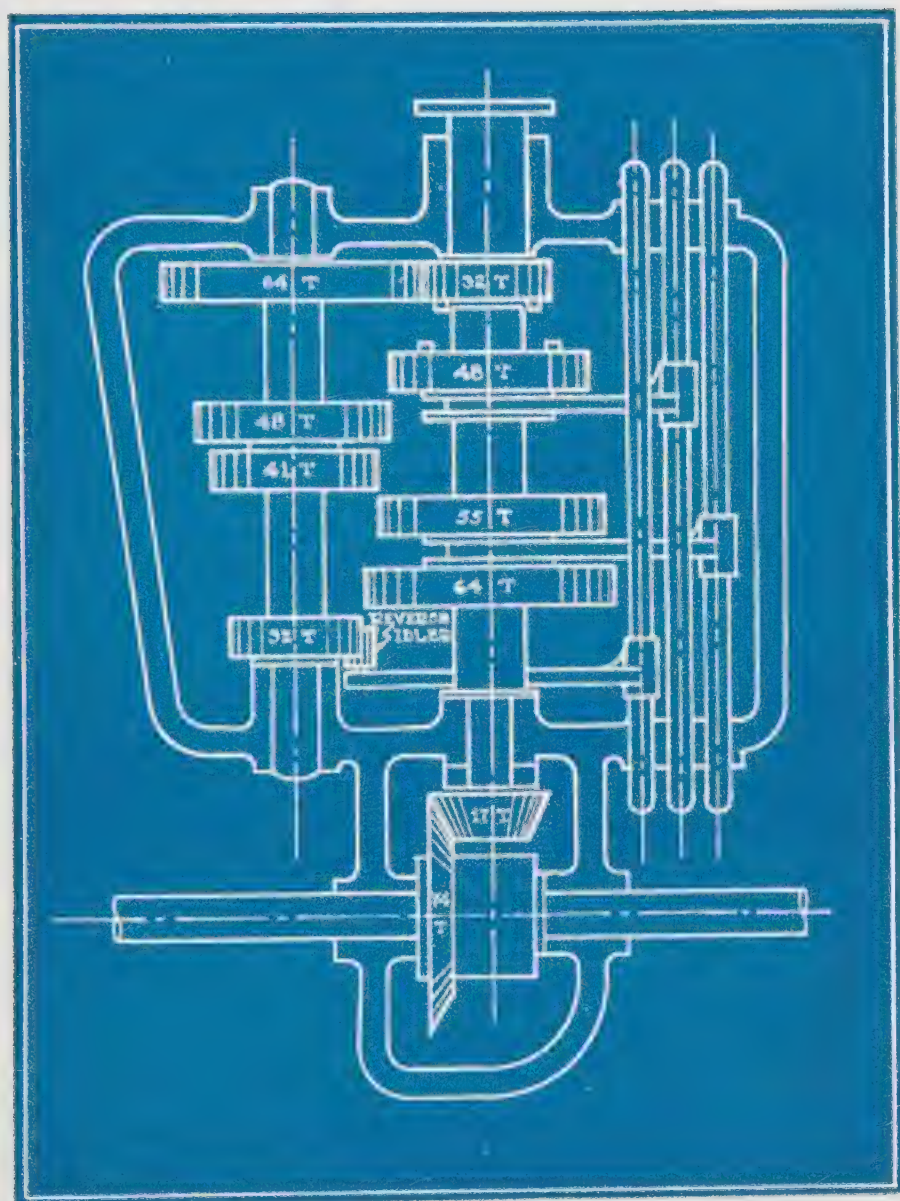
EXERCISES

A four-speed selective transmission for a truck can be seen in the blue print on page 15. In this case first speed and reverse are the same. Find the transmission ratio for:

1. First speed. 2. Second speed. 3. Third speed. 4. Fourth speed.
5. Find the rear axle ratio.

Find the total gear reduction for each of the following speeds:

6. Low speed. 7. Second speed. 8. Third speed. 9. Reverse.
10. If the driving bevel pinion was changed to a 15 T gear and the differential gear was changed to a 63 T gear, find the rear axle ratio and total gear reduction for first, second, third, and fourth speeds.
11. Draw two parallel shafts and place on them the gears necessary for a four-speed selective transmission. Place a bevel pinion on the driving shaft in mesh with the differential gear.
12. In ex. 11, find the rear axle ratio, transmission ratio and total gear reduction for each speed.



SPEED RATIOS**SPEED IN MILES PER HOUR**

The speed of an automobile in miles per hour can be determined by using the following formula:

$$M.P.H. = \frac{R \times P \times D \times \pi \times 60}{P_1 \times 12 \times 5280},$$

when

R = Revolutions per minute of engine,

P = Product of the number of teeth on driving gears,

P_1 = Product of the number of teeth on driven gears,

D = Diameter of the wheels.

The value of π is $22/7$, 60 is the number of minutes in one hour, 12 the number of inches in one foot, and 5280 the number of feet in one mile.

ILLUSTRATIVE PROBLEM

Find the number of miles per hour for the 1st speed, fig. 1, page 17 when the engine runs at 1200 R.P.M.

Rule.—

$$M.P.H. = \frac{R \quad P \quad D \quad \pi}{(32 \times 29 \times 61) \times 12 \times 5280 \times 7} \times 60 = 11.41.$$

P_1

Therefore the miles per hour at 1st speed is 11.41.

EXERCISES

In fig. 1, page 17, find the M.P.H. for the following speeds:

1. Second speed. 2. Third speed. 3. Reverse.

In fig. 2, page 17, find the M.P.H. for the following speeds:

4. First speed. 5. Second speed. 6. Third speed. 7. Reverse.

8. In fig. 1, find the rear axle ratio, transmission ratio and total gear reduction when the engine is running 2000 R.P.M.

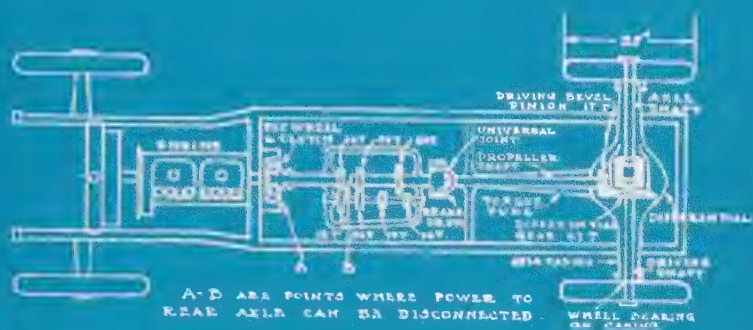


FIG. 1.

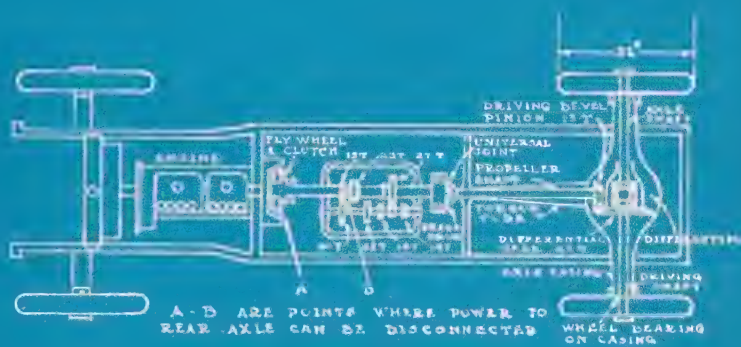


FIG. 2.

SPEED RATIOS**MILES PER HOUR**

The figures on page 19 indicate the method of transmitting the power to the rear axle in chain-driven vehicles. The number of teeth in the sprockets vary with the different makes.

Find the transmission ratio for each of the following speeds in fig. 1, in the blue print, page 19:

1. First speed. 2. Second speed. 3. Third speed. 4. Reverse.

Find the miles per hour for the following speeds in fig. 1:

5. First speed. 6. Second speed. 7. Third speed. 8. Reverse.

Note: The sprockets on a chain-driven truck are used in the same manner as gear teeth. Figure 2 is a four-speed selective type transmission, the reverse speed being the same as first speed, an idler being interposed between gears 14 T and 40 T to give the reverse motion.

9. Find the transmission ratio for the first, second, third and fourth speeds in fig. 2.

In fig. 2, find the miles per hour for each of the following: 10. First speed. 11. Second speed. 12. Third speed. 13. Fourth speed.

14. Find the total gear reduction of all speeds in fig. 1.

15. Find the total gear reduction for all speeds in fig. 2.

16. Make a sketch of a four-speed selective transmission connected to a chain-driven axle as in fig. 2. The constant mesh gears are 25 T and 50 T. The other gears on the countershaft are 39 T, 35 T and 31 T, while the gears on the main shaft are 36 T, 40 T and 44 T. On the driving bevel pinion are 17 T, which mesh with the differential gear of 52 T. The smaller sprocket has 13 T, the rear axle sprocket 96 T. The wheels are 30" in diameter.

17. In example 17 find the miles per hour for each speed when the engine rotates 1000 R.P.M.

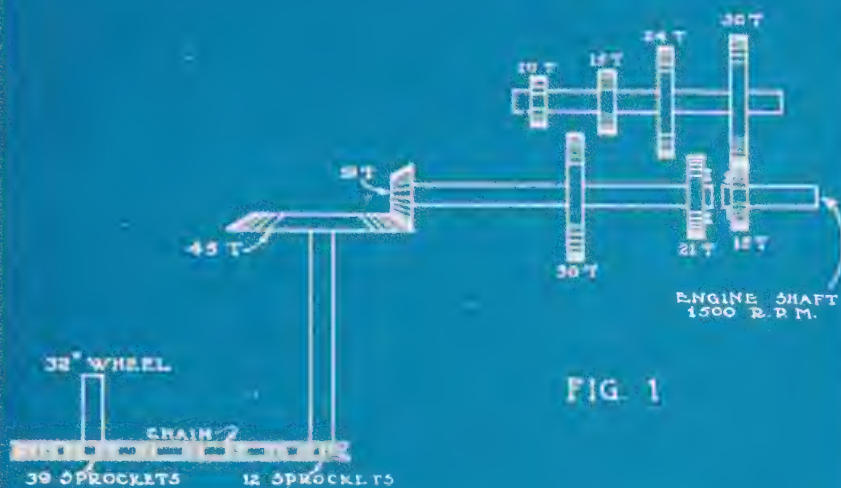


FIG. 1

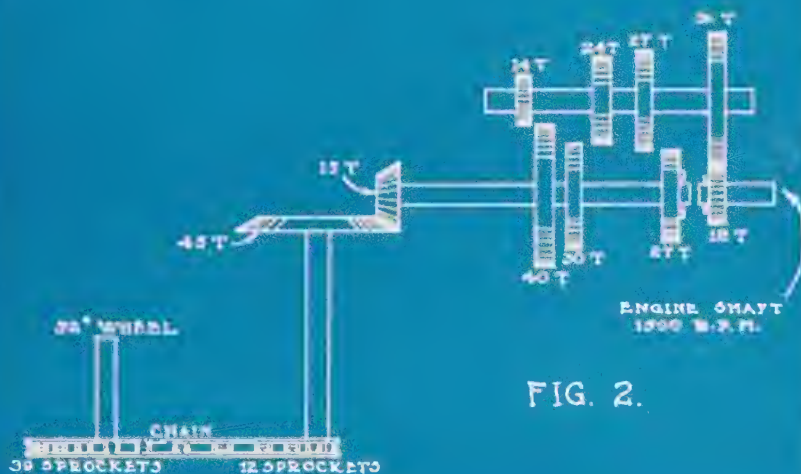


FIG. 2.

SPEED RATIOS

REVIEW EXERCISES

1. What is the purpose of transmission gears in an automobile?
2. Find the rear axle ratio when the driving pinion has 21 teeth and the differential gear 83 teeth.

Find the transmission ratio in each of the following cases:

Driving Gears				Driven Gears			
3.	18	teeth	and 26 teeth		36	teeth	and 29 teeth.
4.	17	"	" 14 "		34	"	" 37 "
5.	16	"	" 29 "		32	"	" 19 "
6.	15	"	" 22 "		30	"	" 23 "

7. In each of the above examples find the total gear reduction, using the rear axle ratio of example 2.

8. Make a sketch of a three-speed selective transmission showing the connections with engine and rear end. The driving gears have the following number of teeth: 28, 14, and 19. The driven gears have 20 and 29 teeth respectively. The constant mesh gears are 16 teeth and 32 teeth, while the driving pinion on propeller shaft has 19 teeth and the differential gear 68 teeth. Find the rear axle ratio, transmission ratio, and total gear reduction.

9. When an automobile climbs a steep hill it is sometimes necessary to shift from high speed to second or first speed. Do the transmission gears increase the horsepower of the motor?

10. Make a sketch of a chain-driven truck with a four-speed selective transmission. The constant mesh gears of the transmission have 22 teeth and 44 teeth; the driving gears 33 teeth, 28 teeth and 20 teeth; the driven gears 46 teeth, 38 teeth and 33 teeth; the reverse pinion 15 teeth; the driving bevel pinion 18 teeth and the differential bevel gear 63 teeth, while the driving sprocket has 12 teeth and the sprocket on the rear wheel has 96 teeth.

11. In example 10 find the R.P.M. of the driving shaft at each of the four speeds when the engine is rotating at 1500 R.P.M.

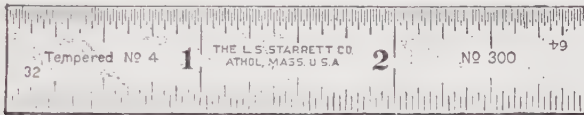
12. In example 10 find the rear axle ratio, transmission ratios, and the total gear reduction.

CHAPTER II

MEASURING INSTRUMENTS

STEEL SCALES

The automobile repair man is constantly requested to measure different lengths and thicknesses. For measurements of ordinary accuracy a steel scale usually six inches in length, with graduations reading eighths and sixteenths on one side and thirty-seconds and sixty-fourths on the other, is used. Two kinds are shown below.



Steel Rule.



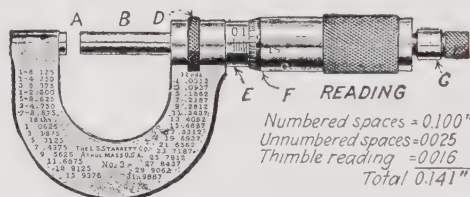
Narrow Hook Rule.

These scales are thin tempered steel and come in lengths from 2" to 24" long. The one most commonly used is 6" long with graduations reading eighths and sixteenths of an inch on one side and thirty-seconds and sixty-fourths of an inch on the other side. However, to correctly measure the clearance of a spark-plug gap or measure the thickness of shims for adjusting crankshaft bearings, an instrument of a higher degree of accuracy is required, because these measurements are usually in one thousandths of an inch. There are two types of instruments which will measure spaces as small as 0.001". These are called "micrometer caliper" and "vernier caliper."

MEASURING INSTRUMENTS

MICROMETER CALIPER

A micrometer caliper, usually called micrometer, is shown in the figure below:



The frame is solid and has a fixed nut on one side. The freely moving screw *B* has 40 threads to an inch. The barrel *E* has 40 graduations to the inch. Therefore, one complete turn of the thimble *F* which is attached to the screw makes the thimble travel one graduation on the barrel or $1/40$ inch, which equals $0.025''$. Every fourth graduation on the barrel is numbered 1, 2, 3, etc., making the distance between these graduations equal to $4 \times 0.025''$ or $0.100''$. Because the beveled edge of the thimble is graduated into 25 equal parts, each of these equal parts would be $1/25$ of one turn or $1/25 \times 0.025'' = 0.001''$.

The locknut *D* tightens against the screw to keep it from turning. The ratchet stop *C* allows the correct pressure to be used for each setting.

Before using a micrometer caliper, care should be taken to see that it is properly adjusted. The *O* mark on the thimble *F* should coincide with the line along the axis of the barrel *E* when the ratchet stop *C* turns the screw *B* against the anvil *A*.

Note: No one can learn to use a micrometer without having one to work with. For a clear understanding of this work the student should have a micrometer in his hand and actually set the instrument for each exercise.

MEASURING INSTRUMENTS

MICROMETER CALIPER

DIRECTIONS FOR READING A MICROMETER

Rule.—Count each numbered or large graduation on *E* as $0.100''$ or $0.200''$ or $0.300''$, etc.; each unnumbered or small graduation is counted in thousandths, as 25, 50, 75, etc., while each graduation on thimble is counted as 1 one thousandth.

In fig. 1, we add $0.100''$ for the numbered or large graduations to $0.050''$ for the two unnumbered or small graduations, the reading being $0.150''$.

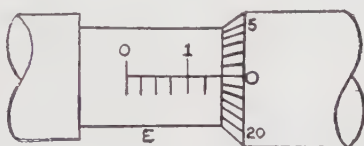


FIG. 1

Barrel	
Numbered Graduation.....	$0.100''$
Unnumbered Graduation.....	0.050
	$0.150''$

In fig. 2, we add $0.200''$ for the numbered or large graduations to $0.025''$ for the unnumbered or small graduations together with $0.014''$ for the 14 graduations on the thimble, the reading being $0.239''$.

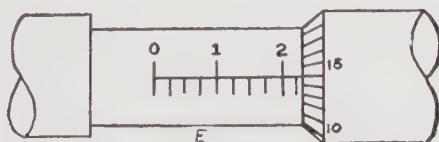


FIG. 2

Barrel	
Numbered Graduations.....	$0.200''$
Unnumbered Graduations.....	0.025
Thimble Graduations.....	0.014
	$0.239''$

Note: In shop practice the addition is done mentally.

MEASURING INSTRUMENTS

MICROMETER

EXERCISES

Find the micrometer reading for each figure in the blue prints on page 25.

- | | | | |
|------------|-------------|------------|------------|
| 1. Fig. 1. | 2. Fig. 2. | 3. Fig. 3. | 4. Fig. 4. |
| 5. Fig. 5. | 6. Fig. 6. | 7. Fig. 7. | 8. Fig. 8. |
| 9. Fig. 9. | 10. Fig. 10 | | |

11. If the thimble of a micrometer is given four complete turns, how far has caliper opened or closed?

12. Through how many turns must the thimble be moved to open a micrometer 0.375"?

13. What decimal part of an inch is a micrometer caliper opened when the thimble is given two complete revolutions?

14. In exercise 13, what fractional part of an inch?

15. Reduce $\frac{5}{16}$ " to a decimal to the nearest 0.001" and tell how you would set the caliper to obtain this reading.

16. What is the diameter of a piece of stock when the reading of the numbered graduations on the barrel is 8 and the thimble reading is 24?

17. If the thimble of a micrometer is given eighteen complete turns, what part of an inch is the micrometer opened?

18. What part of an inch is indicated by the first line beyond 0 on the barrel?

In the following table *A* represents the reading of the numbered graduations on the barrel of a micrometer, *B* the reading of the unnumbered graduations on the barrel, and *C* the thimble reading. Copy the table and insert the number representing the reading of each setting in the blank spaces in the column marked *D*.

	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
19.	5	2	18	
20.	3	0	6	
21.	0	0	24	
22.	4	4	4	



FIG. 1



FIG. 2



FIG. 3



FIG. 4



FIG. 5



FIG. 6



FIG. 7



FIG. 8

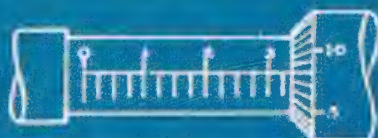


FIG. 9

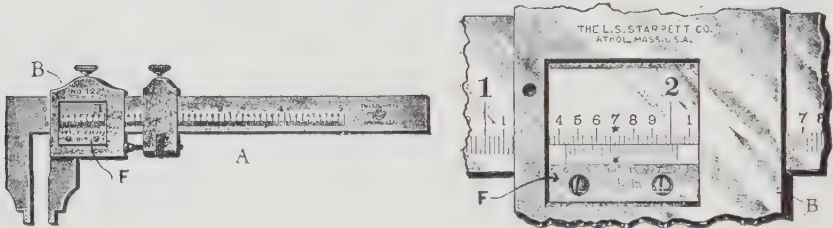


FIG. 10

MEASURING INSTRUMENTS

VERNIER CALIPER

The vernier caliper shown below is named after Pierre Vernier, who in 1631 discovered this method of dividing known distances into very small parts.



The beam *A* is divided into inches and tenths of inches, each tenth being divided into four parts. Therefore, each unnumbered space equals 0.025".

$$1'' \div 10 = 0.100''.$$

$$0.100'' \div 4 = 0.025''.$$

The vernier *F*, fastened to sliding head *B*, is divided into 25 parts numbered 0, 5, 10, 15, 20, 25, and the whole length of these 25 parts is equal to 24 divisions (40ths of an inch) on the beam. Hence 25 parts of the vernier cover but 24 divisions on beam *A* and each of these 25 parts will be 1/25 of 1/40 or 1/1000 of an inch shorter than each division on beam *A*.

Note: No one can learn to use the vernier caliper without having one to work with. For a clear understanding of this work the student should have a vernier caliper in his hand and actually set the instrument for each exercise.

MEASURING INSTRUMENTS

VERNIER

The vernier is based on the principle that, although the eye cannot easily decide the fractional part of a small space, it can readily tell when two lines appear to coincide.

DIRECTIONS FOR READING A VERNIER

Rule.—Note the number of inches and sub-divisions of an inch that the zero mark of the vernier scale *F* has moved along the scale on beam *A*, and then add as many thousandths as there are divisions between the vernier zero and that line on the vernier which coincides with one on scale *A*.



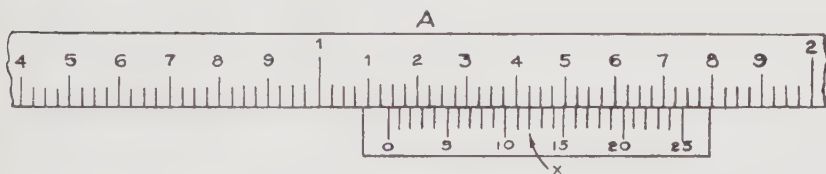
Beam *A*—Whole inches 0

Tenths300''

Thousandths075''

0.375''

The zero coincides exactly with the third line after the numbered line 3 on the bar *A*.



Beam *A*—Whole inches 1.000''

Tenths100''

Thousandths025''

Vernier012''

1.137''

The zero being between two unnumbered spaces, the reading is taken on the line that coincides with scale *A*.

MEASURING INSTRUMENTS

VERNIER

EXERCISES

Find the vernier reading for each of the figures in the blue prints on page 29.

1. Fig. 1. 2. Fig. 2. 3. Fig. 3. 4. Fig. 4.
5. Fig. 5. 6. Fig. 6. 7. Fig. 7. 8. Fig. 8.

9. What are the readings on the beam scale and on the vernier scale of a vernier caliper for a thickness of $\frac{5}{8}$ "?

10. What part of 1" is indicated by the twentieth line from the zero mark on the beam of a vernier caliper?

11. How would you set the vernier caliper to read 0.718"?

12. Reduce $\frac{3}{8}$ " to a decimal and give the reading of the vernier caliper to correspond with this measurement.

13. What part of 1" is indicated by the eighth line from 0 on the beam of a vernier caliper?

14. How would you set a vernier caliper to read 0.002"?

15. How would you set a vernier caliper to read 3.787"?

16. What are the readings on the beam scale and on the vernier scale of a vernier caliper for a thickness of $\frac{9}{16}$ "?

17. How would you set a vernier caliper to read 0.769"?

18. What part of 1" is indicated by the ninth line from the zero mark on the beam of a vernier caliper?

Read the following settings of a vernier caliper:

	Zero on <i>F</i> between Lines	Coinciding Vernier Line
19.	.050 and .075	15
20.	.100 and .125	3
21.	.900 and .925	19
22.	.475 and .500	7
23.	.250 and .275	22
24.	.125 and .150	11
25.	.000 and .025	1

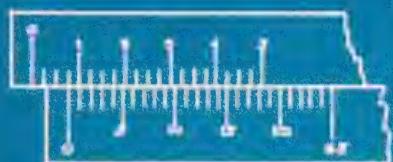


FIG. 1

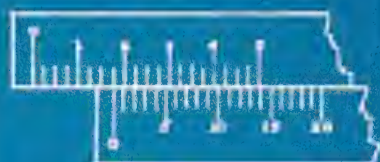


FIG. 2

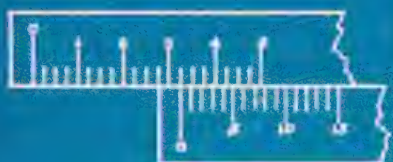


FIG. 3

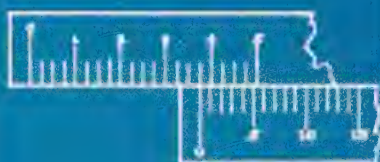


FIG. 4

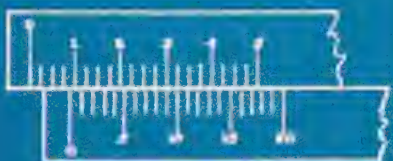


FIG. 5

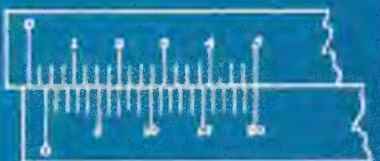


FIG. 6

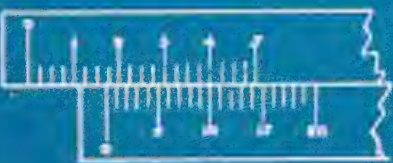


FIG. 7

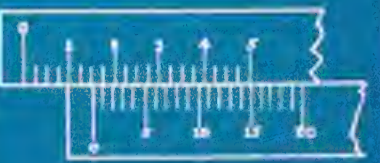


FIG. 8

MEASURING INSTRUMENTS

VERNIER AND MICROMETERS

EXERCISES

1. How do the unnumbered divisions on the beam scale of a vernier caliper compare with the unnumbered ones on a micrometer caliper?

2. How far does the screw of a micrometer move at each revolution of the thimble?

3. A mechanic takes a micrometer caliper which is fully closed and gives the thimble five revolutions. What is the opening of the caliper?

4. What part of an inch is indicated by the line numbered 7 on the beam of a vernier caliper?

5. On a micrometer caliper the barrel reading is 5 and the thimble reading is 14. What is the size of opening of the micrometer?

6. If, when the screw is against the anvil, the thimble is given $\frac{2}{5}$ of a turn, what is the reading of a micrometer caliper?

7. How would you set a vernier caliper to read $0.984''$?

8. How many turns must you give the thimble of a micrometer caliper to measure a thickness of $\frac{1}{8}''$?

9. Which, if either, gives the more accurate measurements, a vernier caliper or a micrometer caliper? State fully the reason for your answer.

10. In measuring a piece of work with the micrometer the following readings were made, each by a different student: $0.778''$, $0.775''$, $0.777''$, $0.776''$, $0.775''$. What is the probable diameter and what the greatest error?

11. Are the readings with the vernier caliper as easy as with a micrometer caliper?

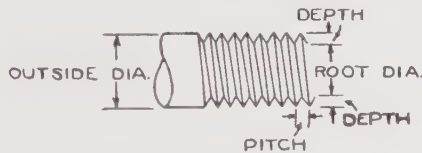
Set the vernier caliper for the following measurements:

- | | | | |
|-----------------------|----------------|------------------------|----------------------------------|
| 12. $.019''$. | 13. $.752''$. | 14. $.226''$. | 15. $.562''$. |
| 16. $\frac{7}{8}''$. | 17. $.163''$. | 18. $\frac{9}{16}''$. | 19. $\frac{3}{8}\frac{1}{4}''$. |

CHAPTER III

SCREW THREADS

Screw threads of various types are used in making an automobile; in fact there is hardly a part in the entire mechanism that does not have its quota of screws, bolts, and nuts. The sketch below shows the principal parts of a screw thread which is generally designated by the diameter of its body, the number of threads per inch, and by the shape of the thread.



As can be seen from the sketch above, a thread is formed by cutting a uniform spiral groove around a bar.

OUTSIDE DIAMETER

The diameter of the stock on which the thread is cut is called the outside diameter of a thread.

DEPTH

The perpendicular distance measured from the outside diameter to the bottom of the groove is called the depth of the thread and twice this depth is called the double depth of the thread.

ROOT AND ROOT DIAMETER

The bottom of the groove is called the root of the thread and the diameter of the screw measured at the bottom of the groove is called the root diameter.

SCREW THREADS

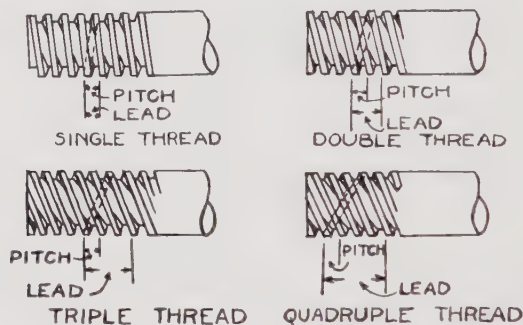
MULTIPLE THREADS

Pitch

The distance from the center of one thread to the center of the next thread is called the pitch of the screw thread.

Lead

The lead of the screw is the advance that the screw makes in one revolution. In a single thread the lead is equal to the pitch. In a double thread the lead is twice the pitch. In a triple thread it is three times the pitch; in a quadruple thread it is four times the pitch, etc.



Multiple Thread

A thread formed by cutting two or more uniform spiral grooves around a bar is called a multiple thread. A multiple thread is said to be a double, triple or quadruple thread and so on according as the number of grooves thus cut is two, three, four, and so on.

Right-Hand Thread

A screw that advances when turned clockwise is called a right-hand screw. This is the common form.

Left-Hand Thread

A screw that advances when turned counterclockwise is called a left-hand thread.

SCREW THREADS

EXERCISES

1. A screw has 12 single threads to the inch. Find the pitch and the lead of the screw.

2. In the double thread screw suppose there are 12 threads to the inch; that is, 6 double threads. Find the pitch and lead of the screw.

3. In a single thread of $1\frac{3}{4}''$ outside diameter the depth is $\frac{3}{16}''$. Find the root diameter.

From the figure on page 31 it is evident that the root diameter is equal to the outside diameter minus the double depth of thread and therefore determines the drill size.

4. If a triple thread has a pitch of $\frac{1}{16}''$, what is the lead of the thread?

5. If the root diameter of a thread is $\frac{7}{16}''$ and the depth is $\frac{3}{8}''$, find the outside diameter of the screw.

6. A quadruple thread has 20 threads to the inch. Find the pitch and the lead.

7. A cross slide on a lathe is moved by a screw that has 16 threads per inch and one revolution of the screw moves the slide $\frac{1}{4}''$. How would you designate the thread?

8. How many revolutions must be made by a triple thread feed screw of $\frac{2}{3}$ inch pitch in order to move the table which it controls $1\frac{1}{2}''$?

9. When the adjusting screw on a drill press makes one revolution it moves the table $\frac{1}{4}''$. If the screw has 8 threads to the inch, how would you designate the thread?

10. When the screw that moves the jaw of a vise makes one revolution it moves the jaw $0.200''$. If the screw has 5 threads to the inch, how should the thread be designated?

11. A pipe thread has $11\frac{1}{2}$ threads per inch. What is its pitch?

12. The depth of a certain thread is $.0156''$. What is the root diameter of the screw whose outside diameter is $\frac{1}{8}''$?

13. What is the lead of a $\frac{1}{8}''$ pitch quadruple thread?

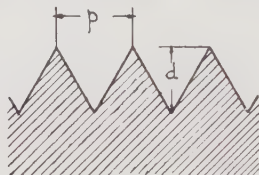
14. What is the pitch of a triple-threaded screw having a lead of $\frac{3}{8}''$?

SCREW THREADS

SHARP V THREADS

Sharp V Thread

The thread of which the cross-section is an equilateral triangle is called a sharp V thread. Since the cross-section of this thread is an equilateral triangle all the angles are 60° . The depth of the



p, pitch; d, depth

thread is the altitude of the triangle and the pitch is equal to the base, as is evident from the figure at the right. In a sharp V thread the pitch and depth of the thread are found by the following formula:

$$\text{Pitch} = \frac{1}{\text{number of threads per inch}}$$

METHOD OF FINDING THREADS PER INCH

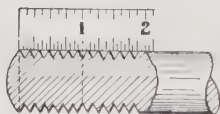


FIG. 1. By means of a steel scale

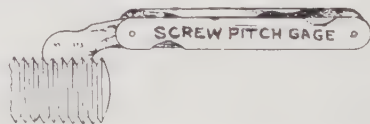


FIG. 2. By means of a screw pitch gage

$$\text{Depth} = \frac{0.866}{\text{number of threads to } 1''} = 0.8660 \times \text{pitch}.$$

ILLUSTRATIVE PROBLEMS

Find the depth of a sharp V thread with 20 threads to $1''$.

$$\text{Pitch} = \frac{1}{\text{number of threads to } 1''} = \frac{1}{20}.$$

$$\text{Depth} = 0.866 \times \text{pitch} = .866 \times 1/20 = 0.043.$$

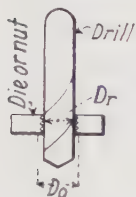
Therefore, the depth of a sharp V thread with 20 threads to $1''$ is $0.043''$. (Give the dimension correct to the nearest $0.001''$.)

SCREW THREADS

SHARP V THREADS

EXERCISES

1. Find the depth of a sharp V thread with a pitch of $\frac{3}{4}$ ".
2. Find the depth of a sharp V thread with 11 threads per inch.
3. Find the double depth of a sharp V thread with 7 threads to the inch; with 14 threads to the inch.
4. Find the depth of a sharp V thread with $4\frac{1}{2}$ threads to the inch; with $3\frac{1}{4}$ threads to the inch.
5. Find the tap-drill size of a sharp V thread tap, which has an outside diameter of $\frac{5}{16}$ " and 18 threads per inch.



Note: Tap-drill size means the size of the drill necessary to drill for a certain sized tap. From the sketch it is evident that for a full thread the tap-drill size is equal to the root diameter.

6. A screw having 7 sharp V threads to the inch has a root diameter of 1.0651. Find the outside diameter.
7. Find the tap-drill size for a sharp V thread tap which has an outside diameter of $2\frac{3}{4}$ " with 4 threads per inch.
8. If the root diameter of a sharp V thread screw is 5.2302" and the outside diameter is 6", what is the depth of the thread and the number of threads per inch?

Find the double depth of a sharp V thread, given that the pitch of each thread is as follows:

9. $1/18$ ". 10. $1/12$ ". 11. $1/5$ ". 12. $1/11$ ". 13. $1/7$ ".
14. Find the tap-drill size for a tap $1\frac{7}{8}$ " in diameter with $3\frac{1}{2}$ sharp V threads to the inch.
15. Find the root diameter of the following sharp V threads: $\frac{1}{4}$ "—20, $\frac{5}{16}$ "—18, $\frac{5}{8}$ "—11, $\frac{15}{16}$ "—9, $1\frac{3}{8}$ "—6, 3 "— $3\frac{1}{2}$.

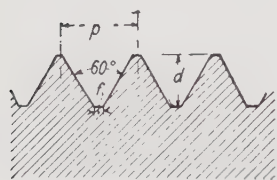
Note: The common method of expressing the size of a screw is $\frac{1}{4}$ "—20. This means that the body of the screw is $\frac{1}{4}$ " and has 20 threads per inch.

SCREW THREADS

American National Threads

Coarse Thread Series

A sharp V thread flattened an equal amount at the top and bottom, as here shown, is known as the American National thread, coarse-thread series. It was formerly called the United States Standard thread.

Fine-thread Series

d, depth; f, flat; p, pitch

A thread of the same shape as the coarse-thread, but which differs only in the number of threads per inch, is known as the American National Fine Thread Series. It was formerly known as the S. A. E. thread. In both of these threads the following formulas are used:

$$\text{Depth} = \frac{0.6495}{\text{number of threads to } 1''} = 0.6495 \times \text{pitch}.$$

$$\text{Flat (top and bottom)} = \frac{1}{8} \times \text{pitch}.$$

ILLUSTRATIVE PROBLEMS

A. Find the depth of an American National screw thread of 20 threads to 1''.

$$\text{Depth} = 0.6495 \times 1/20 = .0325$$

Therefore the depth of an American National screw thread of 20 threads to 1'' is 0.0325''.

B. Find the width of the cutting tool for the above thread.

$$\text{Flat} = 1/8 \times \text{pitch} = 1/8 \times 1/20 = 1/160 = 0.006''.$$

Therefore the flat of the cutting tool is 0.006''.

A gage such as shown on the right is usually provided for grinding the cutting tools.



SCREW THREADS

AMERICAN NATIONAL THREADS

EXERCISES

1. From the formula on page 36 of the depth of an American National thread with 16 threads to the inch.

2. Find the depth of an American National thread of $1/6''$ pitch.

3. Find the tap-drill size for a $1\frac{3}{8}''$ —12 American National thread.

4. Find the double depth of an American National thread of $1/14''$ pitch.

5. If the root diameter of an American National thread is $3.7982''$ and there are $2\frac{7}{8}$ threads to the inch, what is the outside diameter of the screw?

6. What is the root diameter of an American National thread $\frac{9}{16}''$ —18 thread?

7. Find the tap-drill size of a $4\frac{1}{4}''$ American National thread with $2\frac{3}{8}$ threads per inch.

8. If the root diameter of an American National thread of $1/14''$ pitch is $0.9072''$, what is the outside diameter?

Find the width of the point of a thread tool for cutting each of the following numbers of American National threads to the inch:

9. $2\frac{3}{8}$. 10. $4\frac{1}{2}$. 11. $5\frac{1}{2}$. 12. 9. 13. $2\frac{7}{8}$. 14. 13.

Note: The width of the point of the cutting tool is the same as the width of the flat at the bottom of the groove:

15. If the root diameter of an American National thread is $1.3918''$ and the outside diameter is $1\frac{1}{2}''$, what is the depth of the thread?

16. Find to the nearest $1/64''$ the proper size of drill for boring a hole which is to be tapped with a full $1\frac{1}{8}''$ —7 American National thread; with a full $\frac{3}{8}''$ —24 thread.

Copy and fill in the missing specifications in the following:

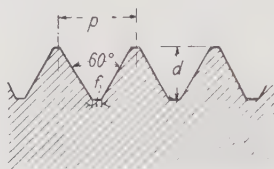
	Outside Diameter	Number of Threads per Inch	Pitch	Double Depth	Root Diameter
17.	$1\frac{5}{8}''$	$5\frac{1}{2}$			
18.	$2\frac{1}{2}''$	4			
19.	$3\frac{1}{4}''$	$3\frac{1}{2}$			
20.	$5\frac{3}{4}''$	$2\frac{3}{8}$			

SCREW THREADS

METRIC THREADS

A metric thread is similar in shape to the American National thread shown on page 36, but the measurements are in millimeters (mm. = 0.0394).

Of the two standard metric threads in general use, the first is the International Standard Thread adopted at Zurich in 1898 and the second is the French Standard. There is very little difference between them.



d, depth; f, flat; p, pitch

The following formulas are used with both threads:

$$\text{Depth} = \frac{0.6495}{\text{number of threads to } 1''} = 0.6495 \times \text{pitch}.$$

$$\text{Flat (top and bottom)} = \frac{1}{8} \times \text{pitch}.$$

ILLUSTRATIVE PROBLEMS

Find the depth of an International Standard thread of 3 millimeter pitch. Also find the flat of the cutting tool.

$$\text{Depth} = 0.6495 \times \text{pitch} = 0.6495 \times 3 = 1.9385.$$

Therefore, the depth of a 3 millimeter pitch International Standard thread is 1.9 mm.

In problems dealing with metric thread, give final results to the nearest 0.1 mm., unless otherwise specified.

$$\text{Flat} = \frac{1}{8} \times \text{pitch} = \frac{1}{8} \times 3 = \frac{3}{8}.$$

Therefore the flat of the cutting tool will be $\frac{3}{8}$ ".

SCREW THREADS

METRIC THREADS

EXERCISES

1. Find from the formula on page 38 the depth of a French Standard thread of 2 millimeter pitch.

2. Find the depth of an International Standard thread of 0.75 mm. pitch.

3. Find the double depth of a French Standard thread of $2\frac{1}{2}$ mm. pitch.

4. Find the root diameter of 22 millimeter International Standard thread of $2\frac{1}{2}$ mm. pitch.

5. Find the pitch of a French Standard thread of which the outside diameter is 42 mm. and the root diameter is 36.15 mm.

6. Find the outside diameter of an International Standard thread of which the root diameter is 39.15 mm. and the pitch is 4.50 mm.

Find the width of the point of a thread tool for cutting each of the following metric threads, the pitch being:

7. 0.25 mm.

8. 0.69 mm.

9. 2.75 mm.

10. 3.5 mm.

11. 5.25 mm.

12. 7.75 mm.

13. If the root diameter of a French Standard thread is 18.75 mm. and the pitch is 2.5 mm., what is the outside diameter of the screw?

14. If the outside diameter of an International Standard thread is 76 mm. and the root diameter is 67.56 mm., what is the pitch of the thread?

15. Find the pitch of an International Standard thread of which the outside diameter is 27 mm. and the root diameter is 23.10 mm.

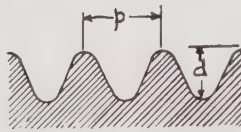
Copy and fill in the missing specifications in each of the following:

	Outside Diameter Mm.	Pitch Mm.	Double Depth	Root Diameter
16.	8	1.25		
17.	11	1.5		
18.	12	1.75		
19.	18	2.5		
20.	24	3		

SCREW THREADS

WHITWORTH THREADS

The thread of which the cross-section is the form shown below is called the Whitworth Standard thread. This thread was devised by Sir Joseph Whitworth and with slight modification is still the British Standard. It is used on cars made in Great Britain. In such a thread the depth and the radius are found by the following formulas:



d , depth; p , pitch

$$\text{Depth} = \frac{0.6403}{\text{number of threads of } 1''} = 0.6403 \times \text{pitch},$$

$$\text{Radius} = \frac{0.1373}{\text{number of threads to } 1''} = 0.1373 \times \text{pitch}.$$

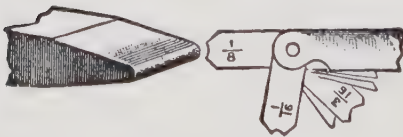
ILLUSTRATIVE PROBLEM

Find the depth of a Whitworth thread of 10 threads to 1'' and the radius of the cutting tool.

$$\text{Depth} = 0.6403 \times \text{pitch} = 0.6403 \times 1/10 = 0.0643.$$

Therefore, the depth of a Whitworth thread of 10 threads to 1'' is 0.0643''.

$$\text{Radius} = 0.1373 \times \text{pitch} = 0.1373 \times 1/10 = 0.0137.$$



Therefore the radius of the cutting tool is 0.0137''.

A gage such as shown on the left is necessary for grinding the tools correctly.

SCREW THREADS

WHITWORTH THREADS

EXERCISES

1. Find the depth of a Whitworth thread of 1/9" pitch.
2. Find the double depth of a Whitworth thread with 24 threads to an inch.
- Find the radius for the point of the tool for cutting a Whitworth thread of which the pitch in each case is as follows:
3. 1/5". 4. 1/6". 5. 1/7". 6. 1/11". 7. 1/32". 8. 1/60".
9. Find the tap-drill size for a Whitworth thread with an outside diameter of 7/8" and 9 threads per inch.
10. If the root diameter of a Whitworth thread is 3.3231" and there are 3 threads to the inch, what is the outside of the screw?
11. If the root diameter of a Whitworth thread is 2.9810" and there are 3 1/4 threads to the inch, what is the outside diameter of the screw?
12. Find the root diameter of a Whitworth thread with an outside diameter of 11/16" and 11 threads per inch.
13. If the outside diameter of a Whitworth thread is 2 7/8" and the root diameter is 2.5091", what is the pitch?
14. Find the root diameter of a Whitworth thread with an outside diameter of 4 1/2" and 2 7/8 threads per inch.
15. If the diameter of a Whitworth screw is 1 1/4", with 7 threads to the inch, what is the pitch? the depth of thread? the root diameter?
16. If the root diameter of a Whitworth thread with 18 threads to the inch is 0.2414", what is the outside diameter?
17. If the diameter of a Whitworth screw is 5", with 2 3/4 threads to the inch, what is the pitch? the depth of thread? the root diameter?
- Copy and fill in the missing specifications in each of the following:

	Outside Diameter	Number of Threads per Inch	Pitch	Double Depth	Root Diameter
18.	1/16"	60			
19.	7/16"	14			
20.	3 5/8"	3 1/4			

SCREW THREADS

SCREW THREAD CUTTING

Threads cut in material less than $\frac{3}{4}$ " in diameter are cut by means of tools shown below.

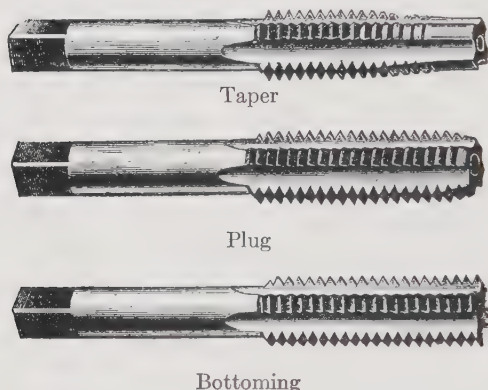


FIG. 1



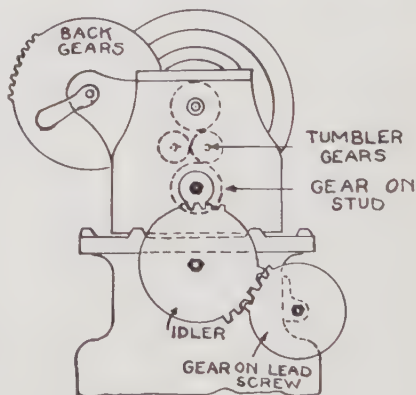
FIG. 2

The set of taps (Fig. 1) are used for cutting small internal threads, while the die (Fig. 2) is used for cutting small external threads.

Threads cut in material $\frac{3}{4}$ " in diameter or larger are usually cut in a lathe, gears of different diameters being interposed between the stud spindle and the lead screw.

Therefore, the selection of the proper change gears is a matter of importance to mechanics.

In order to cut the required number of threads per in., the number of revolutions of the work must be exactly equal to the number of threads to be cut during the time that the carriage carrying the tool moves exactly 1" along the bed of the lathe. Change gears are used so as to give the proper number of revolutions to the lead screw, which moves the carriage, gears of different sizes being placed on the steel shaft and on the lead screw, according to the size of the thread to be cut. The carriage moves slowly for fine threads and rapidly for coarse threads.



SCREW THREADS

SCREW THREAD CUTTING

ILLUSTRATIVE PROBLEM

Find the change gears necessary to cut 12 threads per inch on a lathe that has a lead screw of 6 single threads per inch.

$$\frac{\text{Threads per inch on lead screw}}{\text{Threads to be cut}} = \frac{6}{12}.$$

Multiply both the numerator and denominator by any number that will give the gears in stock on the lathe. In this case,

$$\frac{6}{12} \times \frac{4}{4} = \frac{24}{48}.$$

That is, a gear with 24 teeth should be placed on the end of the stud shaft and a gear of 48 teeth on the lead screw. An intermediate gear of proper size is used to connect the two gears.

Expressed as a proportion we have:

number of teeth on outside stud gear : number of teeth on lead-screw gear = number of threads per inch on lead screw : number of threads per inch on work

whence, $6 : 12 = 24 : 48$.

Variations of Lathes.—The number of threads per inch on the lead screw varies on different makes of lathes, and this makes it necessary to have different sets of change gears. In our problems we shall use the following set of gears:

For a lead screw with 5 single threads per inch, 25—25-30-35-40-45-50-55-60-65-69-70-80-90-100-110-120.

For a lead screw with 6 single threads per inch, 24—24-32-40-44-48-52-56-60-64-72-110.

For a lead screw with 8 single threads per inch, 24—24-28-32-36-40-44-48-52-56-64-69-72-80.

Note: To cut a right-hand thread the lathe carriage progresses toward the head stock. To cut a left-hand thread the motion of the stud gear is reversed by the tumbler gears. The thread is begun at the head stock and cut toward the tail stock.

SCREW THREADS

SCREW THREAD CUTTING

EXERCISES

1. What change gears are required on a lathe with a lead screw of $\frac{1}{6}$ " pitch in cutting a screw thread of 12 threads per inch?

Find the change gears required on a lathe with a lead screw of $\frac{1}{3}$ " pitch for cutting each of the following number of threads per inch:

2. 14. 3. 9. 4. 15. 5. 18. 6. $11\frac{1}{2}$.

Find the change gears required on a lathe having a lead screw with 8 threads per inch for cutting each of the following number of threads per inch:

7. 10. 8. 18. 9. 20. 10. 16. 11. 4.
12. 7. 13. 13. 14. 5. 15. 9. 16. 12.

17. What is the pitch of the thread that is cut on a lathe with a lead screw of $\frac{1}{5}$ " pitch when there is a 25-tooth gear on the stud and a 40-tooth gear on the lead screw?

Find the change gears required on a lathe having a lead screw with 6 threads per inch for cutting each of the following numbers of threads per inch:

18. 10. 19. 18. 20. $27\frac{1}{2}$. 21. 6. 22. 13.

23. Find the largest number of threads per inch that can be cut with simple gearing on a lathe which has a lead screw of $\frac{1}{5}$ " pitch; of $\frac{1}{6}$ " pitch; of $\frac{1}{8}$ " pitch.

24. Find the smallest number of threads per inch that can be cut with simple gearing on a lathe which has a lead screw of $\frac{1}{5}$ " pitch; of $\frac{1}{6}$ " pitch; of $\frac{1}{8}$ " pitch.

25. Find the change gears necessary to cut a thread with a lead of $\frac{3}{8}$ " if the lead screw of the lathe has 6 threads per inch; if the lead screw has 8 threads per inch.

26. If the gear on the stud has 32 teeth and the gear on the lead screw has 64 teeth, what is the pitch of a thread cut on a lathe with a lead screw of eight threads per inch?

CHAPTER IV

IGNITION

All automobiles of the present time use electrical ignition systems which give an electrical spark within the cylinder of the engine, and sets fire to the compressed mixture.

This makes it necessary for the automobile student to know something about electricity and its use.

Although no one can tell just what electricity is, we can become familiar with its laws and applications.

Electricity at rest has few effects of practical value, but electricity in motion drives motors, lights lamps, and aids in the propulsion of the automobile. Therefore we are concerned with electricity only as it moves and does work.

A knowledge of the following terms is needed for a clear understanding of ignition:

Amperes—The current of electricity is measured in amperes, which state the quantity passing through a conductor in one second.

Volts—The pressure which causes the current to flow is measured in volts.

Ohms—The resistance which a conductor offers to the current is measured in ohms.

The terms ampere, volt, and ohm are derived from the names of scientists who have aided in the development of electrical science.

Anything that will permit a current of electricity to pass through it is called a conductor. All metals are conductors; silver, and copper being the best.

Substances such as rubber, china, porcelain, glass, wood fiber, and mica are called non-conductors or insulators.

IGNITION

OHM'S LAW

Amperes

Ohm's Law, which states the relation which exists among current pressure and resistance, is as follows:

The current which an electric pressure forces through a resistance equals the pressure divided by the resistance.

$$\text{Current} = \frac{\text{pressure}}{\text{resistance}}, \quad \text{or} \quad \text{amperes} = \frac{\text{volts}}{\text{ohms}}.$$

ILLUSTRATIVE PROBLEM

If in fig. 1 the lamp has a resistance of 12 ohms and the battery gives a voltage of 6, find the amperes necessary to light the lamp.

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms}} = \frac{6}{12} = 0.5.$$

Therefore the current necessary to light the lamp is 0.5 ampere.

EXERCISES

1. In fig. 2, find the amount of current needed to ring the bell.
2. If the bell had a resistance of 350 ohms, what current will flow?
3. Find the amount of current flowing through resistance R , fig. 3.
4. How much current is needed to run the motor in fig. 4?
5. Find the amount of current necessary to start the motor in fig. 5, if the armature has a resistance of 0.06 ohm.
6. How much current is necessary in fig. 6 to operate the horn?
7. What current is produced by 15 volts acting through 0.17 ohm?
8. How much current flows through an arc lamp which has 25 ohms resistance when 85 volts are applied to it?

Note: The student should derive his own formulas in this and following exercises. Formulas are explained in Chapter V of "General Shop Mathematics."

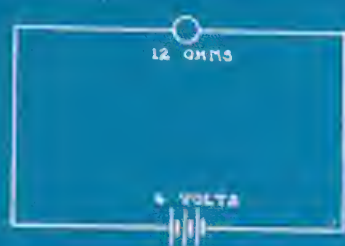


FIG. 1



FIG. 2



FIG. 3



FIG. 4

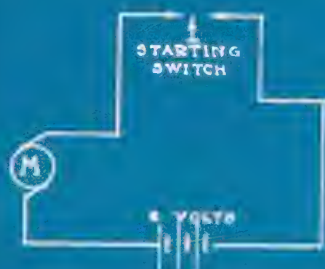


FIG. 5

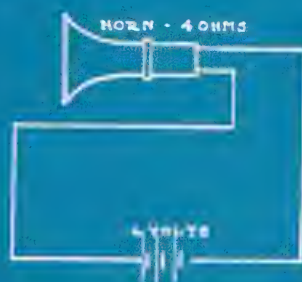


FIG. 6

IGNITION

OHM'S LAW

Voltage

The pressure required to force a given current through a given resistance is the product of the current times the resistance.

$$\text{Pressure} = \text{current} \times \text{resistance, or volts} = \text{amperes} \times \text{ohms.}$$

ILLUSTRATIVE PROBLEM

Find the voltage necessary to force 0.2 ampere through the bell in fig. 1, in the blue print.

$$\text{Volts} = \text{amperes} \times \text{ohms,} \quad 0.2 \times 15 = 3.$$

Therefore, 3 volts are necessary to force .2 ampere through 15 ohms.

EXERCISES

1. In fig. 2, what pressure is needed for the incandescent lamp, if 0.47 ampere of current flows through it?
2. What voltage will produce a current of 12.5 amperes through the resistance in fig. 3?
3. In fig. 4, find the voltage needed to force 1.6 amperes through the horn.
4. What voltage is needed to force 0.375 ampere through the lamp in fig. 5?
5. If the motor in fig. 6 requires a current of 190 amperes for starting, what voltage is required?
6. If a spark plug air gap has a resistance of 2,200 ohms, what voltage is required to force 0.16 ampere through it?
7. The resistance of a telephone receiver is 95 ohms and the current required is 0.008 ampere. What voltage must be impressed across the receiver?
8. A car has an electric heater of 30 ohms resistance which can safely carry 2 amperes of current. How high can the voltage run?

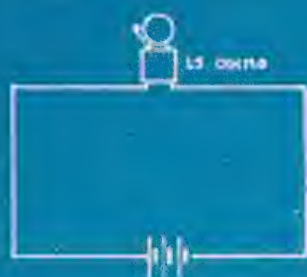


FIG. 1



FIG. 2



FIG. 3



FIG. 4



FIG. 5

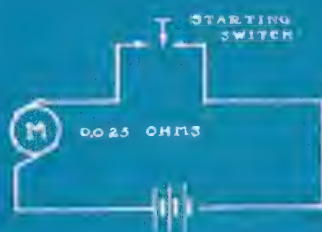


FIG. 6

IGNITION

OHM'S LAW

Resistance

The resistance through which a given pressure will force a given current equals the quotient of the pressure divided by the current.

$$\text{Resistance} = \frac{\text{pressure}}{\text{current}} = \text{ohms} = \frac{\text{volts}}{\text{amperes}}.$$

ILLUSTRATIVE PROBLEM

In fig. 1, what will be the resistance of R , when 6 amperes are flowing in the circuit?

$$\text{Ohms} = \frac{110}{6} = 18.33.$$

Therefore, the resistance will be 18.33 ohms.

EXERCISES

1. What must be the resistance of the lamps in fig. 2, if it takes 1.75 amperes at 5.5 volts pressure?
2. Find the amount of resistance of the relay, fig. 3, if it takes 0.12 ampere at 12 volts pressure.
3. Find the resistance of the motor in fig. 4, when taking 15 amperes of current.
4. What must be the resistance of the horn, fig. 5, if it takes 0.15 ampere of current?
5. What resistance must the bell in fig. 6 have in order to limit the current to 0.018 ampere?
6. If a starting motor requires 90 amperes of current at 6 volts, what is its resistance?
7. What is the resistance of a lamp filament which uses 0.25 ampere at 12 volts?
8. A car heater takes 1.5 amperes when used on a 25-volt circuit. What is its resistance?

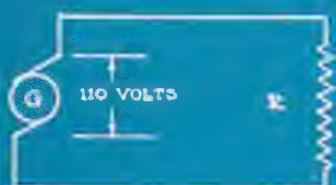


FIG. 1.



FIG. 2



FIG. 3



FIG. 4

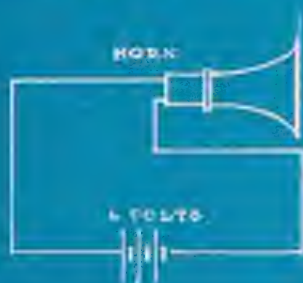


FIG. 5



FIG. 6

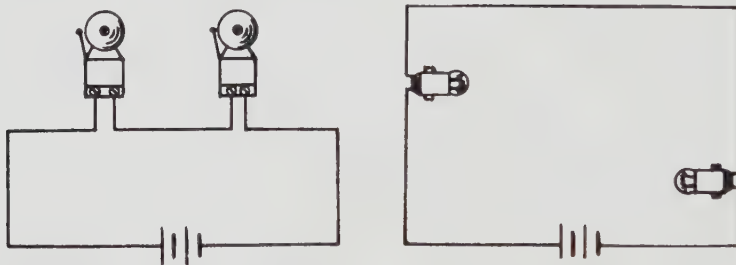
IGNITION

ELECTRIC CIRCUITS

Series Connections

There are two ways of connecting two or more pieces of electrical apparatus: series and parallel. These two combinations may exist in the same circuit. We will consider series connections first.

Pieces of electrical apparatus are said to be in series when they are connected one after the other.

*Rules for Series Combinations*

Resistance of a series combination is the sum of the resistance of the separate parts.

Current through a series combination is same as current through each part.

Voltage across a series combination is the sum of voltage across separate parts.

Ohm's law may be applied to the whole circuit, or to any part of a circuit.

ILLUSTRATIVE PROBLEM

(a) What is the resistance of the circuit in fig. 1?

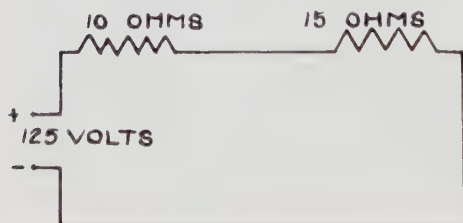


Fig. 1.

Resistance = sum of separate resistance.

$$R = 10 \text{ ohms} + 15 \text{ ohms or } 25 \text{ ohms.}$$

(b) In fig. 1, what current flows in this circuit?

Current = same in each part.

$$\text{Current} = 125 \div 25 \text{ or } 5 \text{ amperes.}$$

IGNITION

ELECTRIC CIRCUITS

Series Connections

ILLUSTRATIVE PROBLEMS

If in fig. 2, five amperes are flowing, find:

- (a) the voltage at the terminals.
 (b) the voltage across each piece.
 (c) the current through each piece.

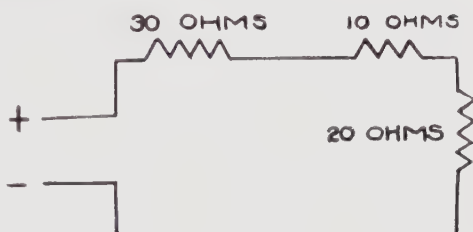


Fig. 2.

Total resistance = $30 + 10 + 20 = 60$ ohms.

Volts to force 5 amperes through 60 ohms = $5 \times 60 = 300$ volts, or answer to (a).

Volts to force 5 amperes through 30 ohms = $5 \times 30 = 150$ volts

Volts to force 5 amperes through 10 ohms = $5 \times 10 = 50$ volts

Volts to force 5 amperes through 20 ohms = $5 \times 20 = 100$ volts

300 volts.

Remember the current should be the same across each part:

$$\text{Current through 30 ohms} = \frac{\text{voltage (across 30 ohms)}}{\text{resistance (across 30 ohms)}} = \frac{150}{30} = 5 \text{ amperes,}$$

$$\text{Current through 10 ohms} = \frac{\text{voltage (across 10 ohms)}}{\text{resistance (across 10 ohms)}} = \frac{50}{10} = 5 \text{ amperes,}$$

$$\text{Current through 20 ohms} = \frac{\text{voltage (across 20 ohms)}}{\text{resistance (across 20 ohms)}} = \frac{100}{20} = 5 \text{ amperes.}$$

Although the 10 ohms resistance is lower than that of the other two resistances, no greater current can flow through it than through the other two. No more electric current can enter at one end of an electric circuit than can get out at the other end.

IGNITION

SERIES CIRCUITS

EXERCISES

1. In fig. 1, what is the resistance of the circuit?
2. In fig. 1, find the amount of current that flows in the 20-ohm lamp.
3. The motor, fig. 2, required 10 amperes of current; find how many volts are used to send current through the line wires.
4. In fig. 2, find the voltage across the motor.
5. In fig. 2, find the resistance of the motor.
6. How much voltage is required to send 0.5 ampere through the lamps in fig. 3?
7. In fig. 4, find the resistance of the combination.
8. How much voltage is required to send 0.6 ampere through the resistance in fig. 4?
9. In fig. 5, what is the current in the line?
10. In fig. 5, find the voltage across the relay.
11. In fig. 5, how much voltage is used in sending the current through the line wires?
12. The ammeter in fig. 6 reads 0.59 ampere and the voltmeter reads 65 volts; find the resistance of R .
13. Find the voltage across the 54 ohms and 38 ohms in fig. 6.
14. Find the voltage at the terminals.
15. A lamp of 25 ohms, another lamp of 30 ohms and a coil of 75 ohms are connected in series. The voltage across the 30-ohm lamp is 90 volts. Find:
 - (a) The current in the lamps and the coil.
 - (b) The voltage across the coil.
 - (c) The total voltage.



FIG. 1



FIG. 2



FIG. 3



FIG. 4

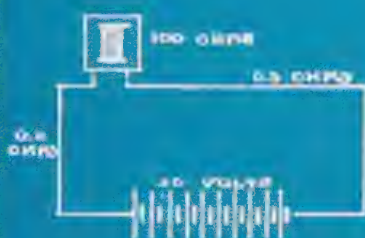


FIG. 5



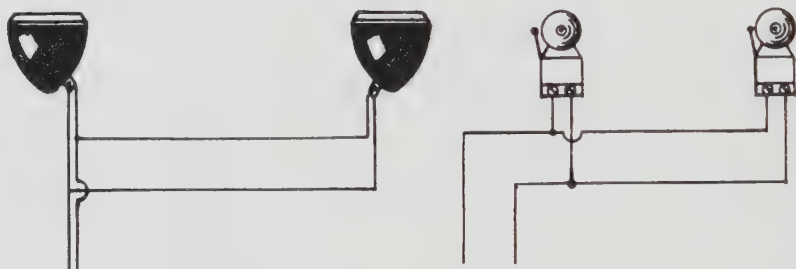
FIG. 6

IGNITION

ELECTRIC CIRCUITS

Parallel Connections

Pieces of electrical apparatus when connected side by side so that the current is divided between them are said to be in parallel or multiple with one another.



RULES FOR PARALLEL CIRCUIT

Resistance

Resistance of a parallel circuit is: The reciprocal of the sum of the reciprocals for the various resistances. The joint resistance is less than the resistance of the branch, having the smallest resistance.

Current

The current through a parallel circuit is: The sum of the currents through the separate branches.

Voltage

Voltage across a parallel circuit is: The same as the voltage across each branch.

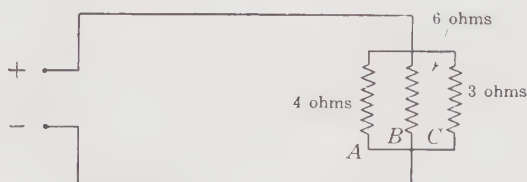
The reason that the joint resistance of two pieces of apparatus in parallel is less than the resistance of either piece alone is that the more paths in parallel to carry the current, the less the resistance. When two pieces of apparatus of equal resistance are connected in parallel, then joint resistance is just half as great as the resistance of either piece.

IGNITION

PARALLEL CONNECTIONS

ILLUSTRATIVE PROBLEM

(a) Find the current flowing in fig. 1, when 12 volts are impressed on the terminals.



F.G. 1.

By Ohm's law, we find:

$$\text{Current flowing in } A = 12/4 = 3 \text{ amperes}$$

$$\text{Current flowing in } B = 12/6 = 2 \text{ amperes}$$

$$\text{Current flowing in } C = 12/3 = 4 \text{ amperes}$$

$$\text{Current through combination} = 9 \text{ amperes.}$$

Note: That the voltage across the combination is the same as the voltage across each branch.

(b) Find the resistance, sometimes called the joint resistance, in fig. 1.

By Ohm's law, we find:

$$\text{Resistance of circuit} = \frac{\text{voltage across circuit}}{\text{current through circuit}} = \frac{12}{9} = 1.33 \text{ ohms}$$

The reason the resistance of a circuit is less than the smallest resistance is because there are more paths in parallel to carry the current.

By the reciprocal method, we have:

$$4 \text{ ohms, the reciprocal of 4 is } \frac{1}{4}, \quad \frac{1}{4} = 3/12$$

$$6 \text{ ohms, the reciprocal of 6 is } \frac{1}{6}, \quad \frac{1}{6} = 2/12$$

$$3 \text{ ohms, the reciprocal of 3 is } \frac{1}{3}, \quad \frac{1}{3} = 4/12$$

$$\frac{9}{12}$$

The reciprocal of $9/12$ is $12/9$ or 1.33 ohms.

or a still better method:

$$\frac{6 \times 4}{6 + 4} = 2.4,$$

The product of the resistances in parallel is divided by their sum.

$$\frac{2.4 \times 3}{2.4 + 3} = \frac{7.2}{5.4} = 1.33.$$

Check. By Ohm's law, volts = amperes $\times$ resistance. In the above problem, 9 amperes $\times$ $1\frac{1}{3}$ ohms = 12 volts, the terminal voltage.

IGNITION

PARALLEL CIRCUITS

EXERCISES

1. In fig. 1, the lamps have the same resistance. The sum of the current taken by the two lamps is 1 ampere. Find the resistance of each lamp.

2. Find the joint resistance of the two bells in fig. 2.

3. What current will flow if the battery gives $3\frac{3}{4}$ volts?

4. In fig. 3, find the voltage across each resistance.

5. In fig. 3, find the current through each resistance.

6. In fig. 3, find the current through the combination.

7. In fig. 3, find the resistance of the combination.

8. If each motor takes 25 amperes in fig. 4, how many amperes must the generator deliver?

9. If in fig. 5 $4\frac{1}{2}$ amperes flow in the line, find the current through each lamp.

10. In fig. 5, find the resistance of each lamp if the generator gives 110 volts.

11. In fig. 5, find the voltage across each lamp.

12. In fig. 5, find the resistance of the combination.

Each lamp in the charging outfit, fig. 6, has a resistance of 110 ohms; find what current flows when:

13. Switch *A* is closed and all the other switches are open.

14. Switch *B* is closed and all the other switches are open.

15. Switch *C* is closed and all the other switches are open.

16. Switch *D* is closed and all the other switches are open.

17. In fig. 6, what is the resistance of the combination when all switches are closed?



FIG. 1

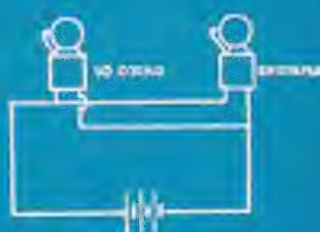


FIG. 2



FIG. 3



FIG. 4

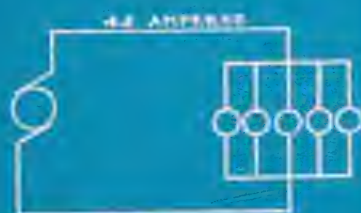


FIG. 5

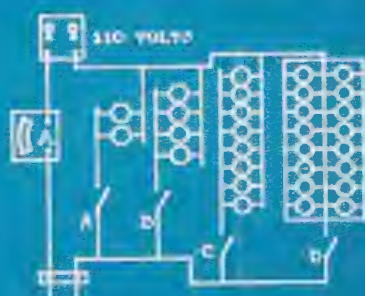


FIG. 6

IGNITION

APPLICATIONS OF OHM'S LAW

EXERCISES

The blue print on page 61 shows a simple style single wire lighting system for an automobile; notice that one connection is grounded, that is, the frame serves as a conductor, the wires being insulated from the frame.

1. The tail and dash lamps are in series and require 0.25 ampere of current at 3 volts pressure for proper lighting; find the resistance of each lamp.

2. In example 1, find the resistance of the circuit.

3. In example 1, find the total current flowing.

4. The two head lamps are in parallel and each has a resistance of 42 ohms. What is the combined resistance of the lamps?

5. In example 4, find the pressure necessary to force 0.5 ampere through the lamps.

6. If the pressure is increased 25%, find the amperage.

7. The combined resistance of the side lamps is 4 ohms. If the resistance of one lamp is 8 ohms, find the resistance of the other.

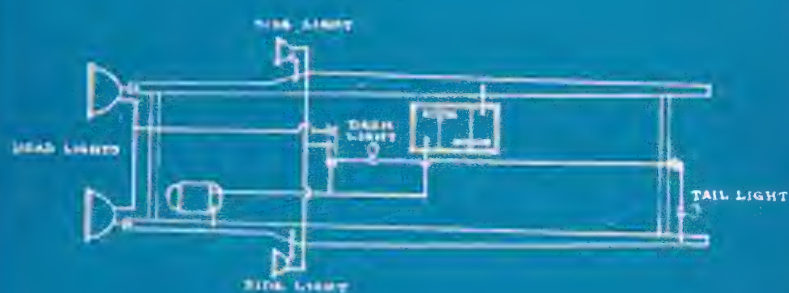
8. In example 7, how much current is flowing through the combination when the pressure is $5\frac{1}{2}$ volts?

9. If the battery gave 12 volts pressure, how much current will be necessary to light the head lamps having a resistance of 75 ohms?

10. What is the resistance of the side lamps when the voltage is 6 and the current through each lamp is 0.42 ampere?

11. What pressure can force 7 amperes through a parallel combination consisting of a 6-ohm branch, a 12-ohm branch and an 18-ohm branch?

12. The terminals of a generator have a pressure of 12 volts. What current will flow if a wire of 0.03 ohm be connected across the terminals?



IGNITION

SERIES AND PARALLEL CIRCUITS

EXERCISES

1. What pressure will be required to force 8 amperes through a parallel combination of 6 ohms, 9 ohms, and 27 ohms?
2. An arc lamp having a resistance of 18 ohms requires 5 amperes of current. Find the resistance that must be added to it when placed on a 110-volt line with the same amperage.
3. What voltage is required across a line where there are 10 lamps in series, each of 220 ohms resistance, if each lamp requires 0.5 ampere to operate it?
4. If three resistances of 18 ohms, 22 ohms, and 20 ohms respectively, are placed in series across a 110-volt line, find what current will flow.
5. A parallel circuit has three branches of 8, 12, and 16 ohms, respectively. If 3 amperes flow in the 16-ohm branch, find the current flowing in each of the others.
6. The combined resistance of two wires in parallel is 2.4 ohms. If the resistance of one wire is 4 ohms, find the resistance of the other.
7. A dash light of 25 ohms resistance is in series with a tail lamp of 40 ohms resistance. If the battery on the car gives 6 volts, what is the current through each lamp, and what is the voltage?
8. A head lamp of unknown resistance is put in parallel with one of 80 ohms resistance. If when a voltage of 16 volts is applied a current of 1.5 amperes flows, what is the resistance of the unknown head lamp?
9. The resistance of a parallel circuit of two branches is 4 ohms. The resistance of one of the branches is 24 ohms. Find the resistance of the other.
10. What voltage is required across a line on which there are 12 lamps in series, each of 6 ohms resistance, if each lamp requires 2 amperes to operate it?

IGNITION

ELECTRIC WORK AND POWER

When one gallon of water is raised one foot by a pump, a certain amount of work is performed and the work is measured in foot-pounds. Likewise, when one ampere is passed through a wire under a pressure of one volt, a certain amount of work is done.

A foot-pound is the unit of work. It is the work done in raising one pound a height of one foot, or it is the pressure of one pound exerted over a distance of one foot in any direction.

The rate at which work is done is called power, and mechanical power is divided into units called horsepower. A horsepower is equal to 33,000 foot-pounds of work done per minute. The power required to keep a current of electricity flowing is the product of the current in amperes by the pressure in volts. The result is the power in watts. The formula is:

$$\text{Watts} = \text{amperes} \times \text{volts}.$$

The watt, which is named after James Watt, the English engineer, is the power represented by 1/746 part of a horsepower, there being 746 watts to one horsepower.

The watt is the largest unit used in automobile ignition and battery charging, but in electrical plants the kilowatt, equal to 1,000 watts, is used.

A watt is the power used when one volt causes one ampere of current to flow. Following are three forms of Power Equation:

$$\text{Watts (power)} = \text{amperes} \times \text{volts}.$$

$$\text{Amperes (current)} = \frac{\text{watts}}{\text{volts}}.$$

$$\text{Volts (pressure)} = \frac{\text{watts}}{\text{amperes}}.$$

IGNITION

ELECTRIC POWER

EXERCISES

1. In fig. 1, what power is consumed by the motor if it takes 8 amperes of current?
2. The lamp in fig. 2 is a 25-candlepower tungsten lamp and requires 1.5 watts per candlepower. What current does it take?
3. R in fig. 3 is the resistance of a car heater. What power does it consume?
4. How much power is consumed by the lamps in fig. 4, if each needs 2.5 amperes for proper incandescence?
5. If each motor in fig. 5 has a resistance of 16 ohms and takes 15 amperes, what voltage must be impressed on the terminals A , B ?
6. What power is consumed by the two motors?
7. If each lamp in fig. 6 has a resistance of 220 ohms, how much current is necessary for the combination?
8. In fig. 6, what power is consumed?
9. A motor is rated to take 10 amperes and to consume 1,000 watts. For what voltage is it built?
10. An arc lamp is rated at 150 watts on an 85-volt line. What current does it take?
11. How many watts are consumed by a starting motor which takes 90 amperes from a 6-volt battery?
12. How many watts are consumed by a 12-volt lamp taking 0.5 ampere?
13. A spark plug air gap has a resistance of 10,000 ohms. What power is consumed when 0.002 ampere is sent through it?
14. An electric car heater has a resistance of 50 ohms and takes a current of 1.6 amperes. What power does it consume?



FIG. 1

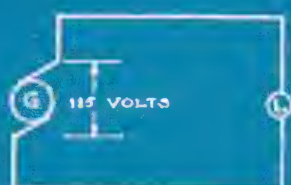


FIG. 2



FIG. 3

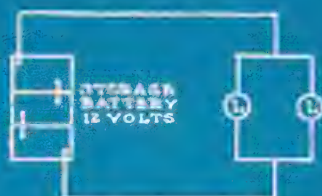


FIG. 4



FIG. 5

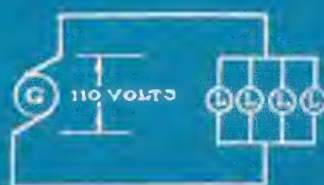


FIG. 6

IGNITION

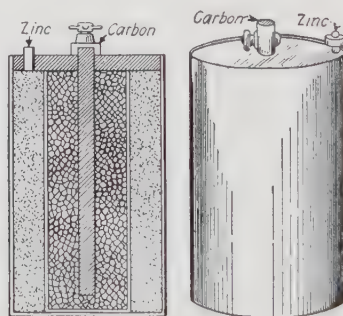
BATTERIES

There are two methods of producing electrical currents—(1) by chemical action, (2) by mechanical action. In the first method, when two dissimilar metals such as copper and zinc are immersed in an exciting fluid and connected by a wire, a current flows through the fluid from one metal to the other. This device is called a cell. When two or more cells are joined in combination so as to form a unit, it is called a battery. The pieces of metal are called electrodes and that terminal from which the current flows is called the plus or positive pole. The other is called the minus or negative pole.

There are two types of cells—(a) primary, (b) secondary.

There are two kinds of primary cells, wet cells and dry cells.

The dry cell is commonly used.



A dry cell is composed of a sal ammoniac paste placed in a zinc can the metal of which forms the negative terminal, and a carbon rod, called the positive terminal, is placed in the center of the paste and held away from the zinc by the hardened paste and insulating cover.

The paste offers a resistance to the flow of the current; this is called the internal resistance of a cell. This in a good dry cell is usually less than 0.1 ohm.

IGNITION

BATTERIES

To find the voltage of a cell it is necessary to place a low reading voltmeter across the terminals when the cell is not delivering any current. This voltage depends entirely upon what plates and chemicals are used, the size making no difference.

The average dry cell voltage is about 1.5 volts. The current delivered by a cell can be determined by Ohm's Law and depends upon the voltage of the cell and the resistance of the entire circuit.

CELL CONNECTIONS

There are three ways of connecting cells:

1. Series—wherein the negative pole of one cell is connected to the positive pole in the next.

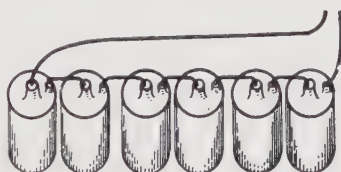


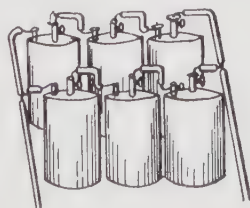
Fig. 1. Series. Zincs connected to carbon.

2. Parallel—wherein all the positive poles are connected to one wire and all the negatives to another.



Fig. 2. Parallel. Zincs connected together. Carbons connected together.

3. Multiple Series—In this system the cells are divided into two equal groups, each group being connected in series, and the two groups being connected with the circuit in parallel with each other.



Note: In the following problems the internal resistance of the cell has been disregarded.

IGNITION

BATTERIES

Series Arrangement of Cells

When cells are connected in series, the voltage of the battery is equal to the result obtained by multiplying the voltage of one cell by the number of cells. A series arrangement is best when the external resistance is high.

ILLUSTRATIVE PROBLEM

In fig. 1, if each cell has a voltage of 1.2 volts, and the bell has a resistance of 72 ohms, find the total volts and the amount of current needed to ring the bell.

$$\text{Volts} = 1.2 \times 3 = 3.6 \text{ volts,}$$

$$\text{amperes} = \frac{\text{voltage}}{\text{resistance}} = \frac{3.6}{72} = .05 \text{ ampere.}$$

Therefore, it takes 0.05 ampere to ring the bell.

EXERCISES

1. In fig. 2, find the voltage and current needed for the relay, if each cell gives 1.55 volts pressure.
2. Find the voltage and current in fig. 3, if each cell gives 0.95 volt.
3. In fig. 4, find the resistance of each lamp, if they need 1 ampere of current and each cell gives 1.2 volts pressure.
4. In fig. 5, find the voltage and current needed if each cell gives .85 volt.
5. Find the combined resistance in fig. 6.
6. In Ex. 5, find the current through each branch, if each cell gives 1.45 volts.
7. What is the greatest current that 12 cells in series, each giving 1.4 volts, can send through a 36-ohm resistance?
8. How many cells in series, each of 1.03 volts, are needed to light a series circuit of three lamps, each of 3 ohms resistance and needing 1.2 amperes for proper lighting?



FIG. 1

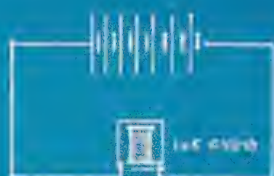


FIG. 2

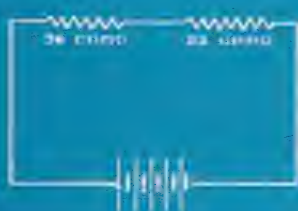


FIG. 3

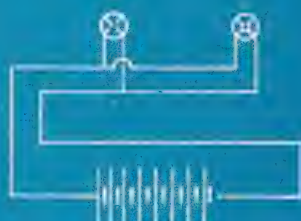


FIG. 4



FIG. 5

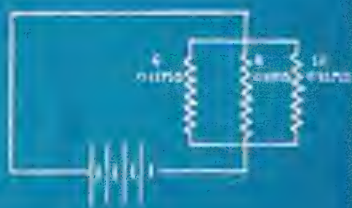


FIG. 6

IGNITION

BATTERIES

Parallel Arrangement of Cells

When cells are connected in parallel, the voltage of the battery is the same as the voltage of one cell. The amperage is that of a single cell $\times$ number of cells. A parallel arrangement is best when the external resistance is very low.

ILLUSTRATIVE PROBLEM

In fig. 1, find the current flowing, if each cell gives a pressure of 1.5 volts.

As the combined voltage is the same as the voltage of one cell, we have

$$\text{amperes} = \frac{\text{volts}}{\text{resistance}} = \frac{1.5}{0.5} = 3.$$

Therefore, there are 3 amperes of current flowing in the circuit.

EXERCISES

1. Find the current necessary for the relay in fig. 2, if each cell has a pressure of 1.1 volts.
2. What amount of current is needed for the lamp in fig. 3, if each cell gives a pressure of 1.25 volts?
3. In fig. 4, find the current flowing, if each cell gives a pressure of 1.46 volts.
4. Find the joint resistance in fig. 5.
5. What current flows through each branch, if each cell gives a pressure of 1.85 volts?
6. What is the reading of the ammeter?
7. In fig. 6, find the current when the cells give a pressure of 0.95 volt.
8. Find the amount of current flowing in a circuit of 1.75 ohms resistance when connected with a battery of 4 cells in parallel if each cell gives a pressure of 1.01 volts.



FIG. 1



FIG. 2



FIG. 3

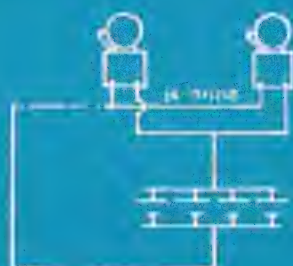


FIG. 4



FIG. 5

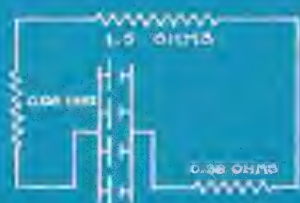


FIG. 6

IGNITION

BATTERIES

Series Parallel Arrangements of Cells

When cells are connected in series parallel, the pressure equals the voltage of one cell multiplied by the number of cells in one row or battery. The amperage is that of one cell multiplied by the number of batteries.

ILLUSTRATIVE PROBLEM

If each cell in fig. 1 gives 1.5 volts pressure, find the voltage in the circuit and the amount of current flowing.

As there are 3 cells in series, $3 \times 1.5 = 4.5$ volts. Since two rows are in parallel, the total voltage would be the voltage of one row.

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms}} = \frac{4.5}{1.5} = 3.$$

Therefore, there are 3 amperes flowing in the line.

EXERCISES

1. In fig. 2, find the total voltage if each cell gives 1.2 volts. Find the current flowing through the lamp.
2. Each cell in fig. 3 gives 0.9 volt. Find the total voltage and the current need for the relay.
3. Find the total voltage in fig. 4, and the current flowing in the line, if each cell gives a voltage of 1.35 volts.
4. In fig. 5, find the total voltage and the current necessary to ring the bell, when the voltage of each cell is 1.1.
5. Find the total voltage in fig. 6 if each cell gives 0.85 volt. What current flows?
6. A battery of 3 parallel sets of 4 cells in series is connected to a circuit of 3.65 ohms resistance. If each cell gives a pressure of 1.13 volts, find the current flowing.

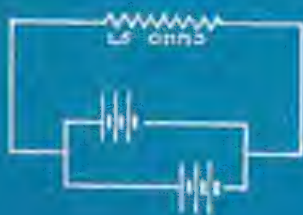


FIG. 1



FIG. 2

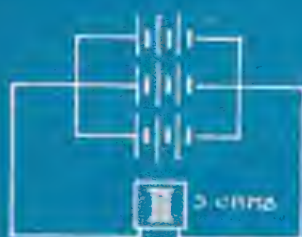


FIG. 3

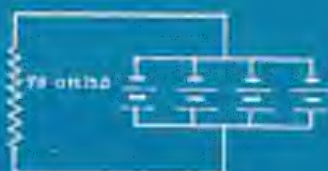


FIG. 4



FIG. 5

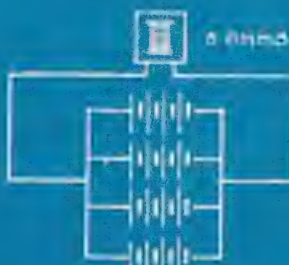
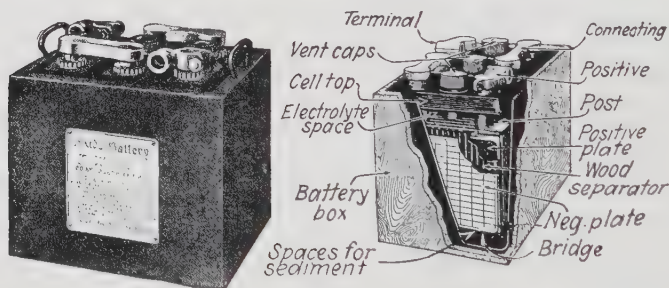


FIG. 6

IGNITION

STORAGE BATTERIES

Besides the primary or dry cell, described on page 66, another type of cell called a secondary cell is used on an automobile. Two or more secondary cells placed in a box of hard wood are called a storage battery. These do not store electrical energy but hold the energy chemically. A cell is composed of a hard rubber jar with bridges at the bottom on which the element or plates rest. The plates are positive and negative and are of different colors, the positive being a deep chocolate color from the lead oxide, and the negative gray from the pure lead. The plates are arranged in groups, either positive or negative, and a positive and negative group together with their separators is called an element.



The fluid placed in the jar with the element is called the electrolyte, which is composed of pure sulphuric acid and distilled or other pure water. The reason for diluting the acid is because sulphuric acid is a heavy oily liquid having a specific gravity of 1.835 and a battery will not operate if the acid is too strong. The normal gravity for a fully charged battery is between 1.270 and 1.300.

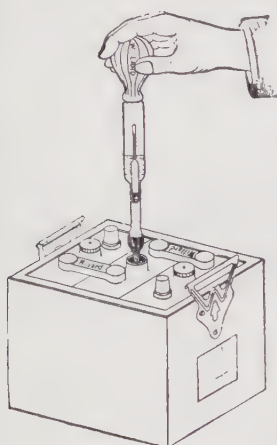
We will discuss this phase of a storage battery.

IGNITION

STORAGE BATTERIES

Specific Gravity

By specific gravity is meant the relative weight of any substance compared with water as a base. Pure water is therefore considered as having a specific gravity of 1, usually written 1.000. One pound of water is approximately one pint, but an equal volume of concentrated sulphuric acid weighs 1.835 lbs. It therefore has a specific gravity of 1.835 which can be measured by an instrument called a hydrometer.



Using Hydrometer

The specific gravity of the electrolyte is affected by a change of temperature, since it expands when heated. Electrolyte becomes lighter or of lower gravity as it gets warmer and vice versa. To overcome this difficulty a standard of 70° F. was adopted as the basis for comparison of specific gravities. A special thermometer is used for this purpose and the reading on the hydrometer must be corrected, if the temperature is above or below 70° F. To do this,



Thermometer

use the following rules:

1. When the electrolyte is warmer than 70° F., add one point to the fourth figure for every 3° above 70°.

ILLUSTRATIVE PROBLEM

The temperature of the electrolyte is 100° F., and the hydrometer reading is 1.260; find the corrected reading.

$$100^{\circ} - 70^{\circ} = 30^{\circ}. \quad 30 \div 3 = 10.$$

Therefore the corrected reading is, using hydrometer, $1.260 + .010 = 1.270$.

IGNITION

STORAGE BATTERIES

Specific Gravities

2. When the electrolyte is colder than 70° F. subtract one point from the fourth figure for every 3° below 70° F.

ILLUSTRATIVE PROBLEM

The temperature of the electrolyte is 49° and the hydrometer reading is 1.230; find the correct reading.

$$70^{\circ} - 49^{\circ} = 21^{\circ},$$

$$21 \div 3 = 7.$$

Therefore the corrected reading is $1.230 - .007 = 1.223$.

EXERCISES

In the following cases copy and find the corrected reading:

	Temperature in degrees	Hydrometer Reading	Corrected Reading
1.	90	1.275	
2.	78	1.260	
3.	40	1.240	
4.	82	1.280	
5.	39	1.235	
6.	58	1.250	
7.	89	1.270	
8.	67	1.255	
9.	73	1.275	
10.	100	1.280	

11. When the temperature of the electrolyte is 53° and the hydrometer reading is 1.237, find the correct reading.

12. If the hydrometer reading is 1.312 and the corrected reading is 1.302, find the temperature of the electrolyte.

IGNITION

RATING OF STORAGE BATTERIES

The capacity of a battery is measured by a unit called ampere-hours. A current of one ampere flowing for one hour is called ampere-hour. The ampere-hours obtainable from a battery depend upon the amount of current consumed by the ignition, starting and lighting system, and the capacity or quantity of electricity the battery is made to deliver. The capacity is independent of its electrical pressure and usually is from 80 to 160 ampere-hours.

ILLUSTRATIVE PROBLEMS

- (a) If a battery gives 10 amperes for 8 hours, what is its capacity?

$$10 \times 8 = 80.$$

Therefore the capacity of the battery amounts to 80 ampere-hours.

- (b) For how many hours will a battery with 50-ampere-hour capacity discharge 12.5 amperes?

$$50 \div 12.5 = 4.$$

Therefore the battery will discharge 12.5 amperes for 4 hours.

EXERCISES

1. What is the capacity of a battery that delivers $12\frac{1}{2}$ amperes for 8 hours?
2. If a starting motor receives 120 amperes of current for 10 seconds, what are the ampere-hours needed for starting?
3. For how many hours will a battery with 120-ampere-hour capacity discharge 7.5 amperes?
4. What is the capacity of a battery that delivers 3 amperes for 19.5 hours?
5. A starting motor receives 90 amperes of current for 8 seconds. What ampere-hours of current were used?

IGNITION

STORAGE BATTERIES

Voltage

The voltage of a storage battery is determined by the number of cells usually connected in series. Each cell gives on open circuit from 2.1 to 2.2 volts when charged, no matter how many plates or the size of the plates. When discharging, a charged battery will give about 2 volts per cell. This loss is due to the internal resistance as can be seen from the exercise below.

ILLUSTRATIVE PROBLEMS

(a) A storage cell has an internal resistance of 0.010 ohm and a pressure of 2.2 volts. What will be the terminal voltage when discharging 20 amperes?

Volts required to send 20 amperes through 0.010 ohm = $.01 \times 20 = 0.20$.
Terminal volts = pressure of cell - volts to overcome internal resistance
= $2.2 - .2 = 2$ volts.

(b) In the preceding example what voltage would have to be impressed across the storage cell in order to charge it at 20 amperes?

Volts to overcome internal resistance, $0.01 \times 20 = 0.2$ volt.
Volts to charge = pressure of cell + volts to overcome internal resistance
= $2.2 + .02 = 2.4$ volts.

This is the starting voltage; the volts at the finish will be about 20% higher.

The voltage should always be measured during the process of charging or discharging at its normal rate. Cells may be fully charged up to about 2.5 volts. The discharge should be stopped when the terminal voltage has dropped to about 1.8 volts at the normal rate of discharge. A battery should never be discharged completely; when testing with a hydrometer the reading of 1.150 is about the limit for batteries used for ignition and lights and 1.225 for starting motors. As you charge your battery the hydrometer readings will increase with the degree of charge. As you discharge your battery the readings will diminish with the degree of discharge.

IGNITION

STORAGE BATTERIES

EXERCISES

1. A storage cell has a pressure of 2 volts and an internal resistance of 0.007 ohm. What is the terminal voltage when discharging 12 amperes?

2. In example 1, find what voltage would have to be impressed across the storage cell in order to charge it at 12 amperes.

Find the voltage when charging and discharging in the following cases:

	Open Circuit Voltage	Internal Resistance	Amperes	
			Charging	Discharging
3.	2.1	0.001	30	8
4.	2.2	0.0015	5	10
5.	2.0	0.003	45	20
6.	2.1	0.002	12	5
7.	1.9	0.004	60	40
8.	2.15	0.006	18	32
9.	1.99	0.0025	15	12
10.	2.05	0.005	20	15

11. If the voltage of a cell is 2.2 volts on open circuit, while the terminal voltage when the cell is delivering 12 amperes is only 2 volts, what is the internal resistance of the cell?

12. A storage cell has an internal resistance of 0.015 ohm and a pressure of 2.01 volts. What will be the terminal voltage when discharging 15 amperes?

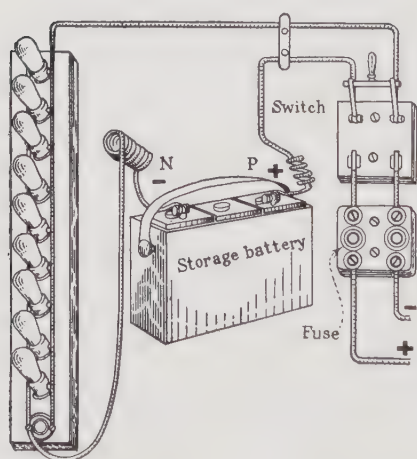
13. In Ex. 12 what voltage would have to be impressed across the cell in order to charge it at 15 amperes?

STORAGE BATTERIES

CHARGING A BATTERY

The charging process consists in forming certain chemical substances by passing electricity through a solution, just as hydrogen and oxygen are formed in the electrolysis of water. To charge, direct current is passed through the cells in a direction opposite to that of discharge. This current, passing through the cells in the reverse direction, will reverse the action which took place in the cells during discharge. The whole object of charging is to drive out the acid absorbed by the plates during discharge and restore it to the electrolyte.

Storage batteries must always be charged from a direct current circuit and great care should be taken to connect the positive wire



to the positive terminal of the battery. It is best to charge a battery at a slow rate for a long time, a 6-ampere rate being a good average for small batteries, and a 10-ampere rate for a 90-100-ampere-hour battery. When storage batteries are charged from a 110-, 220- or a 550-volt direct current circuit, resistance must be used in series with the batteries to reduce the voltage of the circuit to that of the battery.

The method generally employed is to use 50- or 100-watt carbon filament incandescent lamps in parallel with the line, but the modern charging outfits have resistance units.

The illustrative problem on next page will show how to figure the necessary resistance.

CHARGING BATTERIES

ILLUSTRATIVE PROBLEM

If a 3-cell battery, the charging voltage of each cell being 2.5 volts, is to be charged at a 5-ampere rate, find the resistance required when charged from 110-volt line.

If each cell has 2.5 volts, $2.5 \times 3 = 7.5$, total voltage of battery; then,

$$\frac{110 \text{ volts} - 7.5 \text{ volts}}{5 \text{ amperes}} = 20.5.$$

Therefore the resistance required is 20.5 ohms.

EXERCISES

1. Find the resistance required when charging two 3-cell batteries from a 110-volt line at a 6-ampere rate, if the charging voltage of each cell is 2.2 volts.

In each of the following cases find the required resistance when charged from a 110-volt line.

	No. of 3-Cell Batteries	Charging Voltage of Each Cell	Ampere Rate
2.	5	2.1	10
3.	1	2.3	3
4.	3	2.0	6
5.	2	2.45	5
6.	9	2.15	15
7.	4	2.2	8
8.	6	2.35	6
9.	8	1.9	12
10.	2	2.25	4

IGNITION

CHARGING BATTERIES

REVIEW EXERCISES

1. What is the combined resistance of the bank of lamps in fig. 1?

Note: All the lamps used on page 83 are 100-watt, 110-volt, 32 C.P. Each battery has 3 cells.

2. In example 1, find the ampere charging rate if each cell has a pressure of 2.2 volts.

3. Each cell in fig. 2 has a pressure of 2.5 volts, and a 6-ampere charging rate. Have enough lamps been placed in the line to give this rate?

4. If each cell in fig. 3 has a charging voltage of 2.3 volts, find the ampere charging rate.

5. In example 4, find the charging rate if B is disconnected. If B and C are disconnected.

6. Find the number of lamps necessary in fig. 4, if each cell has a charging voltage of $1\frac{5}{8}$ volts and an ampere rate of 8.

7. How many 2.5-volt batteries should be connected in fig. 5 so that they may be charged at a 12-ampere rate?

8. Find the charging rate in fig. 6, if each cell has a charging voltage of 2.2 volts.

9. In example 8, find the charging rate when D is disconnected. C and D are disconnected. When B , C , and D are disconnected.

10. If a 3-cell battery, the charging rate of each cell being 2.4 volts, is to be charged at a 6-ampere rate, find the resistance required when charged from a 110-volt line.

11. A storage cell has an internal resistance of 0.015 ohm and a pressure of 2.35 volts. What will be the terminal voltage when discharging 25 amperes?

12. In example 11, what voltage would have to be impressed on the storage cell in order to charge it at 20 amperes?

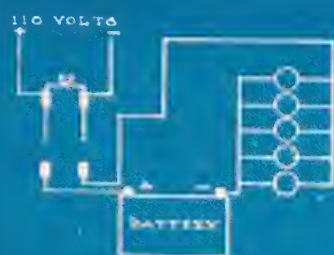


FIG. 1

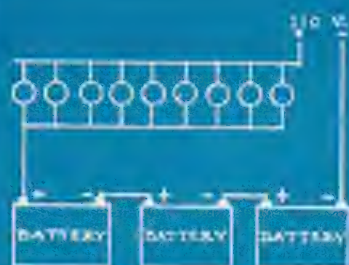


FIG. 2

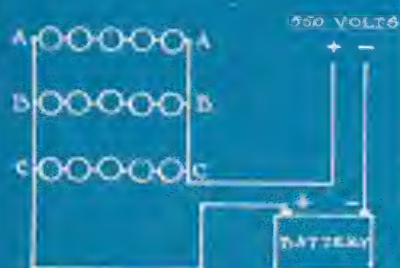


FIG. 3



FIG. 4

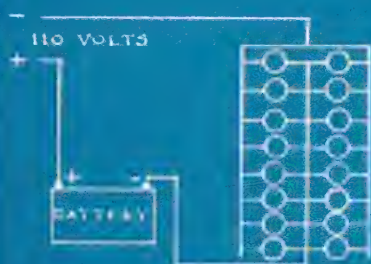


FIG. 5

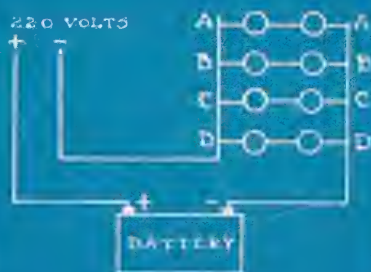


FIG. 6

ELECTRICITY AND MAGNETISM

MAGNETIC CIRCUITS

Magnetism is a property possessed by certain substances, and although it cannot be seen or felt its effects may be seen and felt. Magnetism and electricity are closely related, each being capable of producing the other. Iron, nickle, cobalt and their alloys have magnetic properties, their magnetism being called "Natural Magnetism."

When a number of turns of insulated wire are wound around a soft iron bar and a current is sent through the wire, the bar will

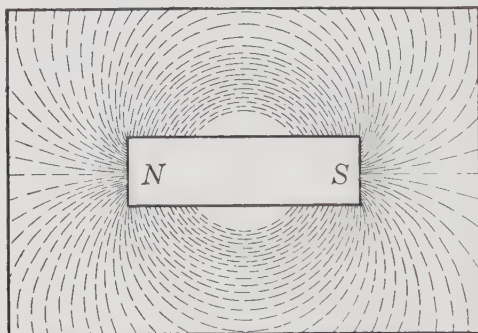


FIG. 1.

have the property called magnetism. Since the bar has this property only when the electric current flows it is called an electromagnet.

If the soft iron bar is replaced by a bar of hard steel and the current is allowed to flow a considerable space of time it will be found that the steel retains the property of magnetism long after the circuit is broken. Since the steel bar retains this property for a longer time than the iron bar it is called a permanent magnet and is said to have a high degree of "retentivity."

If iron filings are sprinkled around a magnet they tend to arrange themselves in certain definite lines as shown in Fig. 1. The lines are curved and appear to concentrate at two definite points

MAGNETIC CIRCUITS

which are called the poles of the magnet. If a small compass is placed near the magnet, it will point in a direction parallel to the filings; if more than one compass is used, the north poles of the compasses will all point to one end of the magnet and the south poles toward the other end. Experiments have proven that the lines, called the magnetic lines of force, or flux, start at one point of the north pole and pass through a south pole back to the north pole. They make various routes depending upon the magnetic substances near them but they always come back to their source. The space through which they pass is called the magnetic field.

A coil of wire wound on an insulating spool is called a solenoid. The winding is always in the same direction, layer upon layer similar to the thread on a spool. If a solenoid is suspended by a thread from the midpoint of its longitudinal axis it will swing into a position with one end pointing north and the other end south.

The north pole of a magnet is called the positive or plus, written (+), pole, and the south pole is called the negative or minus, written (-), pole. It is a phenomenon of magnetism that unlike poles of magnets attract each other and like poles repel each other.

The path which the lines of force take is called the magnetic circuit. The resistance which the various materials making up the circuit offer to the flow of current is one factor in the number of lines of force produced. The other factors, i.e. number of turns of wire, and current strength are discussed on the next page.

EXERCISES

1. What is the difference between natural magnetism and electromagnetism?
2. Define magnetic lines of force.
3. What is a solenoid?
4. What will happen if the north poles of two magnets are placed in contact?
5. Is it possible to make a magnet with only one pole?

MAGNETOMOTIVE FORCE**AMPERE-TURNS**

The magnetism or magnetic flux (total number of lines of force) depends upon the number of turns of wire in the coil of an electro-magnet as well as upon the current strength. For example, 100 amperes of current through 50 turns of wire gives the same result as 40 amperes through 125 turns, for 100×50 , and $40 \times 125 = 5000$.

Rule.—To find the magnetomotive force in ampere-turns, multiply the current in amperes by the number of turns on the coil.

ILLUSTRATIVE PROBLEM

What is the magnetomotive force of a coil with 25 turns through which a current of 3 amperes is passing?

Magnetomotive force $= 3 \times 25 = 75$

Therefore, there are 75 ampere-turns.

EXERCISES

Find the magnetomotive force in each of the following:

	Amperes	Turns of Wire		Amperes	Turns of Wire
1	4	50	6	31.25	125
2	25	450	7	110.6	75
3	15	225	8	27.75	36
4	17.5	60	9	215.9	115
5	80	35	10	76.75	246

11. A current of 27.5 amperes is passing through a coil of 42 turns. Find the magnetotomotive force.

12. Find the magnetomotive force of a coil with 147 turns of wire through which a current of 0.005 ampere is passing.

IGNITION COILS

The purpose of the coils is to convert the low primary current, from the generator or battery, to a high voltage capable of jumping the gap in the spark plug.

The coil consists of two windings placed on an iron core. One winding, called the primary, consists of a few turns of a thick wire which is connected to the battery or generator. The other winding, called the secondary, consists of a great many turns of fine wire.

When the coil is connected to a battery and the circuit closed, a current flows through the primary and a magnetic field is produced. When the circuit is opened the current stops flowing and the magnetic field disappears. Since the magnetic field is continually changing as the primary circuit is made and broken, an electromotive force is induced in the secondary winding by the changing magnetic field.

The ignition coil should require no attention other than to keep the terminal tight. It is important that both the coil and the distributor terminals of the high tension wire be kept clean and **free from** corrosion.

An ignition condenser is used in conjunction with ignition coils to prevent arcing at the ignition contact points when the primary circuit of the coil is broken. On modern high speed engines the condenser performs its duty in $\frac{1}{12000}$ of a second and only works every $\frac{1}{360}$ of a second to fire eight cylinders at an engine speed of 4500 revolutions per minute. The importance of the condenser, ignition coils, and contact points in the operation of the engine may be understood from the fact that, in an eight-cylinder engine, they perform a complete operation eight times as often as any one of the intake or exhaust valves in that engine.

The condenser not only absorbs the spark at the contact points but also changes the direction of **the current in the** primary wire

IGNITION COILS

VOLTAGE

Since each turn of the secondary windings of a well-built coil cuts all the lines of force which are set up by the current in the primary winding, the electromotive force will have the same ratio as the number of turns.

ILLUSTRATIVE PROBLEM

If an ignition coil which has a primary winding of 100 turns and a secondary winding of 100,000 turns is connected to a generator delivering 8 volts, find the voltage at the spark plugs.

Expressed as a proportion:

$$X : 8 = 100,000 : 100$$

$$X = \frac{8 \times 100,000}{100} = 8,000$$

Therefore, the voltage at the spark plugs is 8,000.

Note.—Approximately 6000 volts are required to produce a spark of 0.2 inch in air.

EXERCISES

1. Find the voltage at the spark plugs when a 6-volt generator is connected to a coil which has a primary winding of 50 turns and a secondary winding of 50,000 turns.

2. A coil with a primary winding of 100 turns must deliver 6000 volts when connected to a 6-volt battery. Find the number of turns in the secondary winding.

Find the voltage of spark plugs in each of the following:

	Electromotive Force	Turns of Wire on Primary	Turns of Wire on Secondary
3.	6	10	50,000
4.	8	50	100,000
5.	10	30	75,000
6.	7	75	200,000
7	6.5	80	300,000
8.	12	40	150,000
9.	7.5	25	60,000
10.	8.5	60	85,000

DIRECT CURRENT GENERATORS

A generator is a machine for producing an electric current by the action of a magnetic field. It operates on the principle of electromagnetic induction which is illustrated in Fig. 2. A loop

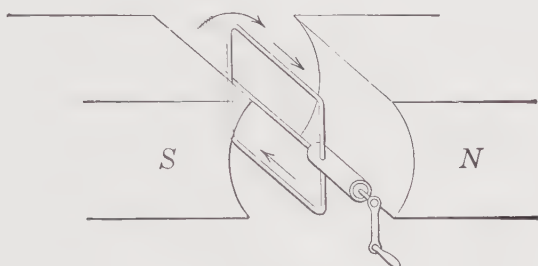


FIG. 2.

of wire revolving between the two poles of a magnet cuts the magnetic lines of force. This sets up an electromotive force in the loop and causes a current to flow around it. The two halves of the wire

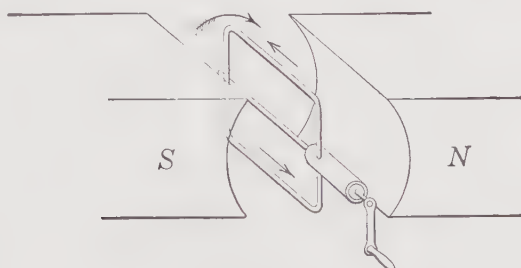


FIG. 3.

cut the lines of force in such a way that the pressures are the same direction as shown by the arrows. Fig. 3 shows the loop of wire after it has been turned through a half revolution from its first position with the two sides of the coil both cutting the lines of force in a direction which is opposite to that in which they cut the lines before. Thus the direction of the current in the loop is reversed and produces an alternating current.

DIRECT CURRENT GENERATORS

As shown in Fig. 4, a connecting device consisting of two collector rings and brushes, insulated from the shaft and from each other, must be used to collect the current for use in an external circuit.

The magnets between which the loop revolves are called field magnets or simply the field. The revolving loop is called the armature.

In order to obtain current flowing in only one direction from a generator, called direct current, it is necessary to intercept the current from the revolving loops in such a way that the electromotive

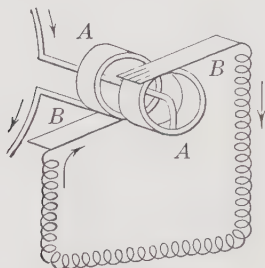


FIG. 4.

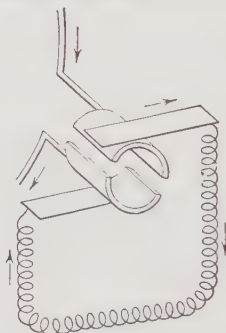


FIG. 5.

force generated by each half revolution is transmitted to separate branches of the external circuit. This is done by substituting one split ring for the two collector rings in Fig. 5. The split ring is called the commutator.

The electromotive force produced by a generator depends upon:

1. The numbers of lines of force cut by the armature wires.
2. The number and length of the cutting wires.
3. The speed at which the armature revolves and the lines of force that are cut.

An electromotive force of one volt is generated when one turn of the loop cuts 100,000,000 lines of force in one second.

Expressed as a formula:

$$E = \frac{\phi Z N}{100,000,000}$$

DIRECT CURRENT GENERATORS

When:

 E = generated electromotive force in volts ϕ = the number of lines of force (flux) per pole Z = the number of active armature conductors N = the speed of the armature in revolutions per second

ILLUSTRATIVE PROBLEMS

1. How many volts are generated in a wire which cuts 2,000,000 lines of force in 20 turns a second?

$$E = \frac{\overset{\phi}{2,000,000} \times \overset{Z}{1} \times \overset{N}{20}}{100,000,000} = \frac{2}{5} = 0.4$$

Therefore, 0.4 volt is generated.

2. What voltage is generated by a generator having 100 active armature conductors on its armature if the number of lines of force per pole is 4,000,000 lines and the armature rotates at 1200 revolutions per minute?

$$1200 \div 60 = 20 \text{ revolutions per second}$$

$$E = \frac{\overset{\phi}{4,000,000} \times \overset{Z}{100} \times \overset{N}{20}}{100,000,000} = 80$$

Therefore, 80 volts are generated.

EXERCISES

1. How many volts are generated in a wire which cuts 8,000,000 lines of force 15 turns in a second?

Supply the missing specifications:

	E	ϕ	Z	N
2.		4,000,000	5	3,000
3.		2,000,000	8	3,600
4.	8		10	3,200
5.	10	3,500,000		3,500
6.	12	2,500,000	6	

EFFICIENCY OF GENERATORS

The efficiency of a generator is defined as the ratio; output of power divided by intake of power.

Expressed as a formula:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} = \frac{\text{output}}{\text{output} + \text{losses}}$$

The losses of power in a generator are:

1. The armature loss i.e., the power which is consumed in the armature windings.
2. The field loss caused by the heat generated in the field windings by the field current.
3. The stray power loss. This includes eddy currents and hysteresis losses mostly in the armature coil, and losses due to friction in the bearings and at the brushes, and also to air friction.

ILLUSTRATIVE PROBLEM

A generator delivers 22 amperes at 8 volts. If the resistance of the armature is 0.02 ohm and the stray power and the field losses equal 14 watts find the efficiency.

$$\text{Armature loss} = I^2 R = 22 \times 22 \times 0.02 = 9.7 \text{ watts}$$

$$\text{Total loss} = 9.7 + 14 = 23.7 \text{ watts}$$

$$\text{Output of generator} = 22 \times 8 = 176 \text{ watts}$$

$$\begin{aligned} \text{Efficiency} &= \frac{\text{output}}{\text{output} + \text{losses}} \\ &= \frac{176}{176 + 23.7} = \frac{176}{199.7} = .88 \end{aligned}$$

Therefore, the efficiency of the generator is 88%.

EXERCISES

Find the efficiency in each of the following:

	Output		Resistance of Armature	Stray Power and Field Losses
	Amperes	Volts		
1.	18	6	0.015 ohm	11 watts
2.	21	7.5	0.025 ohm	15 watts
3.	26	8.7	0.01 ohm	12.5 watts
4.	19	9.1	0.009 ohm	16.2 watts
5.	20.25	7.8	0.017 ohm	8.3 watts

DIRECT CURRENT GENERATOR WINDINGS

Direct current generators are "self-excited," that is, the field coils are excited directly from the armature of the generator, thus producing the magnetic field.

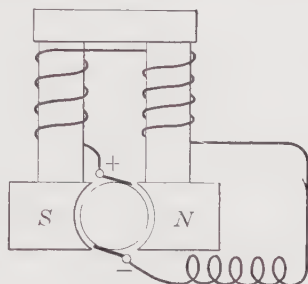


FIG. 6.

There are three kinds of windings for direct current generators:

1. Series wound generator in which the armature and field coils are connected in series, as shown in Fig. 6, so that the same current flows through both.

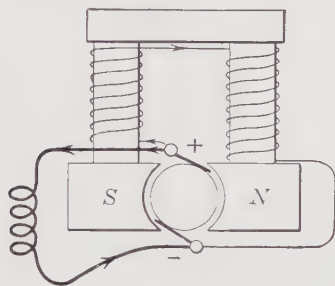


FIG. 7.

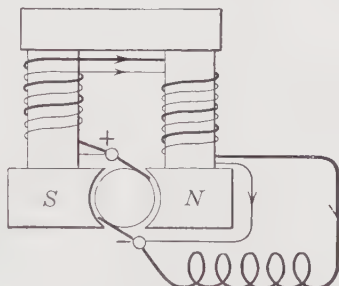


FIG. 8.

2. Shunt wound generator in which the field and armature windings are connected in parallel as shown in Fig. 7. The field windings have a high resistance being made of many turns of fine wire which permits only a small part of total current to flow through them.

3. Compound wound generators in which there are two windings on the field coils as shown in Fig. 8. One is a shunt winding

DIRECT CURRENT GENERATOR WINDINGS

similar to a shunt generator. The other is a winding connected in series with the armature.

The ampere-turns should be the same in all three types to produce the same field strength. In all types, however, the amount of energy used in the field coil is only a small percentage of the total output of the generator.

The voltage characteristics of direct current generators are:

1. The voltage of series wound generators increases with the current output since the field strength increases. However, series generators have few practical uses.

2. The voltage of shunt wound generators decreases as the external current increases: Thus, as the load increases the voltage at the brushes decrease.

3. The voltage of a compound wound generator, the most common commercial type of direct current generator, remain practically constant under all conditions.

Generators used on automobiles are basically shunt wound machines with a third brush current control. They do not run at

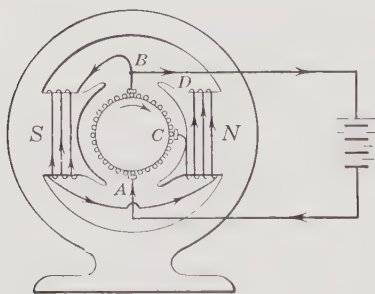


FIG. 9.

a constant speed like the shunt and compound wound generators used in industry but at very great changes of speed since the armature of the generator is driven by the gasoline engine of the automobile. Thus, if there was no voltage control, the voltage would become so great as to not only burn out the filaments of the light bulbs, if they were lighted, but also charge the storage battery at too high a rate.

Fig. 9 shows the circuit used to equalize the voltage. The generator has a two-pole field and the armature delivers current through two brushes to the storage battery. The field coils are connected to the armature through one of the brushes in the battery circuit with a third brush midway between the first two brushes.

DIRECT CURRENT GENERATOR WINDINGS

The current for the battery flows between brush *A* and *B*, while the current for the field coils flows between brushes *B* and *C*. When the armature, through increased speed, starts to deliver a stronger current, the magnetization of the armature is increased. This action shifts the magnetic field in the direction in which the armature is turning and decreases the magnetic strength at the tip of the field pole. Since the magnetic field is weaker there is less electromotive force induced in the coil windings which are passing this pole-tip between *B* and *C*. This results in a smaller amount of current flowing in the field coils since *C* is the place where the armature is connected to the field coils. A resultant lower strength of the magnetic field reduces the voltage bringing it back to what it was at first.

Fig. 10 shows a cross-section view of a present day automobile generator. The location of the non-adjustable third brush that sets the charging rate may be seen together with the field coils, commutator and armature.

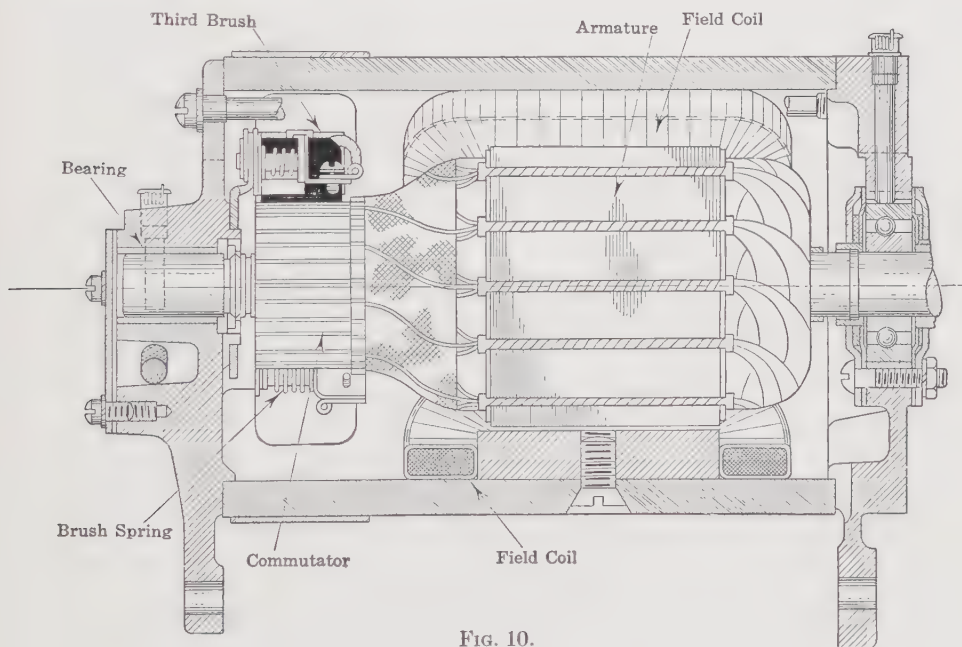


FIG. 10.

ELECTRICITY AND MAGNETISM**REVIEW EXERCISES**

1. What is meant by a magnetic circuit?
2. What is magnetism?
3. What is a solenoid?
4. If two south poles are brought near together, how will they act?
5. Upon what does the total number of lines of force depend?
6. What is the magnetomotive force of a coil with 53 turns through which a current of 5 amperes is passing?
7. What is the purpose of ignition coils?
8. What is the function of the condenser?
9. Is there any difference in the size of the wire used on the primary winding and the secondary winding?
10. If an ignition coil which has a primary winding of 75 turns and a secondary winding of 75,000 turns is connected to a generator delivering 6 volts, find the voltage at the spark plugs.
11. Upon what does the electromotive force produced by a generator depend?
12. What is the principle of electromagnetic induction?
13. What is the purpose of a commutator in a direct current generator?
14. How many volts are generated in a wire which cuts 4,000,000 lines of force in 40 turns a second?
15. How is the efficiency of a generator defined?
16. What is meant by a "self-excited" generator?
17. Make a sketch showing the windings of a series wound generator; of a shunt wound generator; of a compound wound generator.
18. Explain the use of the third brush in the automobile generator.
19. Give the voltage characteristics of direct current generators.
20. Make a sketch showing the winding of an automobile generator.

CHAPTER V

POWER

When a gallon of water is raised a foot in height by means of a pump, a definite amount of work is done and the work done is measured in foot-pounds.

A foot-pound is defined as an amount of work which is done by a force equivalent to a one pound weight, causing a body to move through a distance of one foot. If 15 lbs. are lifted or pushed 2 ft., an amount of work equal to 2×15 or 30 ft.-lbs. is done.

The rate at which work is done is called power, and mechanical power is divided into units called horsepower. One horsepower is equal to 33,000 pounds raised through a height of one foot in one minute, or any proportionate ratio which multiplied together equals 33,000 ft.-lbs. in the same time, e.g., 550 foot-pounds per second.

Power always means the rate of doing work.

THE S. A. E. HORSEPOWER FORMULA

The horsepower of a gasoline engine depends upon the following things: Number of cylinders, area of piston heads, average number of pounds per square inch exerted upon the piston during the working strokes and the R.P.M. of the engine.

From experimentation, the following formula was derived and is used by all leading manufacturers:

$$H.P. = \frac{D^2 N}{2.5}.$$

When D is the diameter or bore of the cylinder and N is the number of cylinders. The speed of the piston was assumed to be 1,000 feet per minute.

Note: This formula was originally adopted by the American Licensed Automobile Manufacturers and later by the Society of Automotive Engineers.

POWER**HORSEPOWER****ILLUSTRATIVE PROBLEM**

Find the horsepower of a four-cylinder engine with a 3'' bore.

$$H.P. = \frac{D^2 N}{2.5} = \frac{3 \times 3 \times 4}{2.5} = \frac{36}{2.5} = 14.4.$$

Therefore the horsepower of four-cylinder engine with a 3'' bore is 14.4.

EXERCISES

1. Find the horsepower of a four-cylinder engine with a $4\frac{1}{2}$ '' bore.

In the following problems find the horsepower:

	Diameter or Bore in Inches	Number of Cylinders
2.	$2\frac{1}{2}$	8
3.	$2\frac{3}{4}$	6
4.	$3\frac{1}{8}$	12
5.	$3\frac{1}{2}$	4
6.	$3\frac{7}{8}$	6
7.	4	12
8.	$4\frac{5}{8}$	8
9.	5	4
10.	$5\frac{1}{4}$	8

11. A six-cylinder gas engine delivers 21.60 horsepower. Find the diameter of the cylinders.

12. A gas engine with a $3\frac{1}{2}$ '' bore delivers 39.22 horsepower. Find the number of cylinders.

POWER

HORSEPOWER

The S. A. E. formula was developed from the following formula which is used not only for gas engines but also for steam engines.

$$H.P. = \frac{PLAN}{33,000},$$

where P is the mean effective pressure in pounds per sq. in.

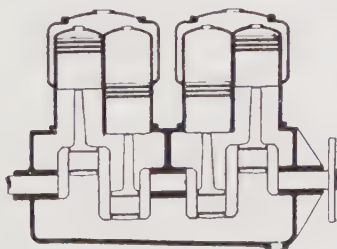
Note: During the entire cycle of a gas engine the cylinder is subject to many variations of pressure. During the power stroke the pressure decreases as the piston proceeds along the stroke. All of this pressure causes the engine to deliver power. In the same way during compression stroke the pressure gradually increases as the piston travels upward, thereby hindering the engine from delivering power. The mean effective pressure is the average of these pressures which in modern gas engines varies between 90 and 120 pounds.

L = length of stroke in feet.

A = area of the base of cylinder in sq. inches.

The area can be found by multiplying the radius² by π ($\frac{22}{7}$) or the diameter² $\times .7854$.

N = the number of power strokes of pistons, i.e., explosion strokes per minute.



Four-Cylinder Engine: crank shaft set at 180 degrees. Power stroke every half revolution.

There are four strokes to two revolutions of the crank. A stroke of the piston means a travel from top to bottom or bottom to top, 180 degrees of movement or one-half a revolution of the crankshaft. There are four power impulses during the four strokes or two revolutions of the crankshaft in a four-cylinder engine and six power strokes in a six-cylinder engine.

POWER

HORSEPOWER

ILLUSTRATIVE PROBLEM

Find the H.P. of a gas engine when the mean effective pressure is 90 lbs., the diameter of cylinder 4'', the stroke 4'' and the number of power strokes per minute is 2500.

$$\begin{aligned}
 H.P. &= \frac{PLAN}{33,000} \\
 &= \frac{P \quad L \quad A \quad N}{33,000} \\
 &= \frac{90 \times \frac{4}{12} \times \left(\frac{22}{7} \times 2 \times 2 \right) \times 2500}{33,000} \\
 &= \frac{90 \times 1 \times 22 \times 2 \times 2 \times 2500}{3 \times 7 \times 33,000} = \frac{200}{7} = 28.57.
 \end{aligned}$$

Therefore the H.P. of the engine is 28.57 at 2500 power strokes per min.

EXERCISES

Find the missing specification in each of the following:

	H.P.	P	L	Diameter	N
1.		110	5''	3½''	3500
2.	46	90	4''		1800
3.	110		4½''	6''	4400
4.	48	115	3''	5''	
5.		95	3½''	2½''	2800
6.	120	100	4¼''		1500

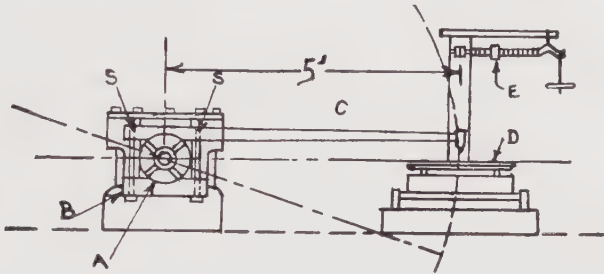
7. Find the H.P. of a gas engine when the mean effective pressure is 98 lbs., the diameter of cylinder 4¼'', the length of stroke 5'' and the number of power strokes per minutes 3100.

POWER

BRAKE HORSEPOWER

The power delivered by the gas inside the cylinder to the piston is called the indicated horsepower (I.H.P.). This can be measured by taking an indicator diagram which shows the pressure of the explosion in pounds per square inch. To actually calculate the horsepower of an engine, a prony brake test must be made. The set up for such a test is shown below.

If an engine develops 8 indicated horsepower and it takes 2 horsepower to drive itself, the crankshaft would deliver 6 horsepower and the rating of the engine would be 6 brake horsepower or 8 I.H.P.



A = fly wheel of engine,

B = wooden clamp on fly wheel, should be lined to prevent jerks,

S = adjusting screws,

C = arm to which clamp is attached,

D = platform of scale,

E = reading for number of pounds pull on arm *C*.

The adjusting screws *S* make it possible to vary the friction between the rim of the flywheel and the wooden clamp. The pull developed by this friction is weighed by the platform scale on which the arm *C* rests. Allowance for the weight of the arm should be made.

POWER

BRAKE HORSEPOWER

Rule.—To find brake horsepower at 1000 R.P.M., open the throttle fully, tighten down clamp by screws *S* until engine is slowed down to required speed of 1000 R.P.M. First measure the distance from the center of the fly wheel to the point of the arm that rests on the scale. Assume the distance to be 5 feet and the number of pounds indicated on the scale to be 20.

Then from the formula

$$B.H.P. = \frac{2 \times \text{center distance of arm in feet.} \times \pi \times \text{R.P.M.} \times \text{number of pounds registered on scale}}{33,000}$$

ILLUSTRATIVE PROBLEM

From the data given above find the B.H.P.

$$B.H.P. = \frac{2 \times 5 \times 22 \times 1000 \times 20}{7 \times 33,000} = \frac{400}{21} = 19.$$

Therefore the engine is developing 19 brake horsepower.

EXERCISES

Find the horsepower developed in each of the following cases:

	Length of Arm in feet	R.P.M.	Reading of Scale in Pounds
1.	4	1500	40
2.	3	1800	35
3.	$3\frac{1}{2}$	1200	30
4.	5	1600	25
5.	$4\frac{1}{2}$	800	20
6.	6	500	30
7.	4	1100	37
8.	7	2000	26
9.	10	850	45
10.	5	1700	32

POWER

HORSEPOWER

REVIEW EXERCISES

1. How much work is done when an automobile draws a load of 800 lbs. a distance of 1 mile?

2. Find the H.P. of a gas engine when the mean effective pressure is 75 lbs., the diameter of the cylinder $3\frac{1}{2}$ ", the length of stroke 3", and the number of power strokes per minute 1000.

In each of the following problems find the missing specification:

	Bore in Inches	Number of Cylinders	Horsepower
3.	$2\frac{5}{8}$	4	
4.	$2\frac{7}{8}$		19.8
5.		6	23.5
6.	$3\frac{3}{8}$	12	
7.		8	45.0

8. If a tackle lifts an automobile weighing 2200 pounds 5 feet from the floor, how much work is done?

Find the missing specifications in each of the following:

	H.P.	P	L	Diameter	N
9.		90	$4\frac{1}{8}$	$2\frac{1}{2}$	2700
10.	20		4	$3\frac{1}{2}$	1800
11.	75	70		$4\frac{1}{2}$	1200
12.	28	85	$3\frac{1}{4}$		4000

13. An engine does 192,000 foot-pounds of work in 5 minutes. Find the horsepower.

14. By pushing a truck against 150 lbs. resistance for 100', how many foot-pounds of work are done?

15. Find the brake horsepower at 1000 R.P.M. when the arm is 8' long and the number of pounds indicated on the scale is 25.

POWER

TORQUE

Torque is the product of force multiplied by the distance at which it is exerted from the center of rotation. When it is said that an engine develops 75 foot-pounds torque, it means that at a distance of one foot from the center of the crankshaft the engine would exert a force of 75 lbs.

Torque usually increases up to a certain R.P.M. of the engine and then decreases, although the horsepower of the engine will increase. Therefore as the pull or force exerted decreases at highest speed, the futility of racing an engine when attempting to pull out of a hole can be seen.

In the prony brake, page 88, the length of the arm *C* is 5 ft., and 20 lbs. pull is registered at *E*; then the torque at 1000 R.P.M. is

$$20 \times 5 = 100.$$

Therefore there are 100 foot-pounds torque.

EXERCISES

Find the foot-pounds torque in each of the following cases:

	Length of Arm in Ft.	Reading of Scale in Lbs.
1.	$4\frac{1}{2}$	20
2.	3	28
3.	$3\frac{1}{2}$	36
4.	5	$18\frac{1}{2}$
5.	4	32
6.	$3\frac{3}{4}$	$27\frac{1}{2}$
7.	$4\frac{1}{4}$	$23\frac{1}{2}$
8.	$5\frac{1}{2}$	$16\frac{1}{4}$

POWER

MECHANICAL EFFICIENCY

The mechanical efficiency of an engine is the ratio between the horsepower available for useful work at the crankshaft (B.H.P.) and the indicated horsepower (I.H.P.).

ILLUSTRATIVE PROBLEM

What is the mechanical efficiency of a gas engine if the brake horsepower (B.H.P.) is 8 and the indicated horsepower (I.H.P.) is 10?

$$\frac{B.H.P.}{I.H.P.} = \frac{8}{10} = .80.$$

Therefore the mechanical efficiency is 80%.

EXERCISES

In each of the following cases, find the mechanical efficiency:

	Brake Horsepower	Indicated Horsepower
1.	11	12
2.	12	15
3.	19	22
4.	$13\frac{1}{2}$	16
5.	31	35
6.	$24\frac{1}{2}$	27
7.	15	18
8.	27	29
9.	$36\frac{1}{2}$	40
10.	28	31

POWER

THERMAL EFFICIENCY

British Thermal Units

The efficiency of a gas engine can also be rated by the ratio of the work actually done, when expressed in heat units, to the total heat supplied in the fuel that enters the combustion chamber. This is called thermal efficiency and is always less than 100%.

When turning iron or sawing wood a part of the energy of work becomes heat. By experiment it has been found possible to determine the number of foot-pounds of work required to raise the temperature of a quantity of water a certain number of degrees.

This mechanical equivalent of heat is measured in British thermal units and 1 B.T.U. equals 778 ft.-lbs. of work, and this amount of heat is sufficient to raise the temperature of 1 pound of water 1° Fahrenheit.

ILLUSTRATIVE PROBLEM

How much heat is equivalent to 15,000 ft.-lbs. of work?

$$1 \text{ B.T.U.} = 778 \text{ ft.-lbs.};$$

$$\text{therefore} \quad \frac{15,000}{778} = 19.3 \text{ B.T.U.}$$

EXERCISES

Find the number of B.T.U. in each of the following cases:

- | | | |
|---|---------------------|---------------------|
| 1. 10,000 ft.-lbs. | 3. 476,270 ft.-lbs. | 5. 166,800 ft.-lbs. |
| 2. 789,250 " " | 4. 76,800 " " | 6. 5,626,420 " " |
| 7. How much heat is equivalent to 280,000 ft.-lbs. of work? | | |
| 8. How many ft.-lbs. of work are equivalent to 5,700 B.T.U? | | |

POWER

THERMAL EFFICIENCY

One lb. of gasoline (.8 of a pint) averages 19,000 B.T.U.

ILLUSTRATIVE PROBLEM

If 1 lb. of gasoline is placed in a cylinder and, during the consumption of this gasoline, 3,890,000 ft.-lbs. of work are received from the crank-shaft, find the B.T.U. and the thermal efficiency.

$$\frac{3,890,000}{778} = 5000 \text{ B.T.U.}$$

The thermal efficiency will be the 5000 B.T.U. divided by the 19,000 B.T.U.

whence
$$\frac{5000}{19,000} = .26 \text{ or } 26\%.$$

EXERCISES

On the basis of 1 lb. of gasoline consumption find the B.T.U. and thermal efficiency for each of the following:

- | | |
|-----------------------|-----------------------|
| 1. 5,000,000 ft.-lbs. | 8. 7,825,200 ft.-lbs. |
| 2. 8,672,400 " " | 9. 4,587,600 " " |
| 3. 7,489,000 " " | 10. 5,750,400 " " |
| 4. 4,962,500 " " | 11. 8,345,000 " " |
| 5. 6,500,000 " " | 12. 3,500,000 " " |
| 6. 9,287,600 " " | 13. 6,750,200 " " |
| 7. 3,922,000 " " | 14. 5,149,000 " " |

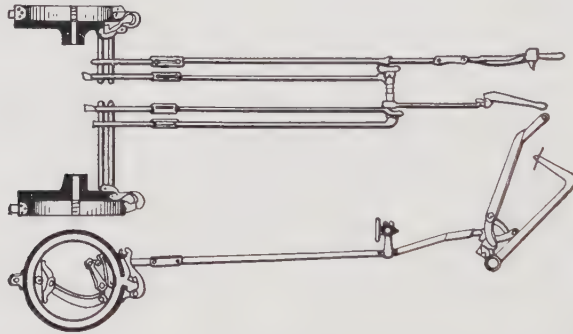
15. If 1 lb. of gasoline is placed in a cylinder, and, during the consumption of this gasoline, 2,775,220 ft.-lbs. of work are received from the crank-shaft, find the B.T.U. and thermal efficiency.

CHAPTER VI

BRAKES

An automobile is equipped with brakes so that its motion may be checked. Automobile brakes are usually drums on rear and front wheels and a very efficient band brake can be obtained on a very moderate diameter of drum.

There are two types of brakes in common use, the external contracting type and the internal expanding type. These types can be combined as shown in the figure below.



When running at 40 or more miles per hour, a vehicle weighing one or two tons makes a large force of inertia which will result in the vehicle running many yards after the engine is shut off. The function of the brakes is to snub this forward movement, and the strain on the brake to affect a stop in a given distance increases as the square of the increase of speed: i.e., a vehicle running at 10 miles per hour requires four times the power to stop it in the same distance as when running at 5 miles per hour.

The brakes of an automobile must be powerful enough to bring the machine to a sudden stop; the safety of the occupants depending upon their proper action.

BRAKES**ACCELERATION**

To determine the brake power necessary to stop a vehicle of given weight running at a given speed in a given distance, it is necessary to figure the work or energy due to acceleration. This can be found from the formula:

$$K = \frac{WV^2}{2G},$$

where K = work or energy of the moving mass.

W = weight of vehicle in pounds.

V = velocity expressed in feet per second.

G = acceleration due to gravity or 32.2 feet per second.

Reducing miles per hour to feet per second so that the units in the equation are the same,

$$1 \text{ M.P.H.} = \frac{5280}{3660} = 1.467 \text{ ft. per second,}$$

whence

$$\frac{WV^2}{2G} = \frac{W \times (1.467)^2}{64.4} = W \times 0.0334,$$

V^2 becoming M^2 .

ILLUSTRATIVE PROBLEM

How many pounds of work are necessary to stop a vehicle weighing 2000 pounds going 10 miles per hour?

$$\begin{aligned} K &= WM^2 \times 0.0334 = 2000 \times (10)^2 \times 0.0334 \\ &= 2000 \times 100 \times 0.0334 = 6680. \end{aligned}$$

Therefore 6680 ft.-lbs. of work are needed.

EXERCISES

In each of the following cases find the number of ft.-lbs.:

	Weight	Miles per Hour		Weight	Miles per Hour
1.	1500 lbs.	20	4.	3 ton	18
2.	4 ton	15	5.	2400 lbs.	40
3.	2800 lbs.	30	6.	$\frac{1}{2}$ ton	25

BRAKES**DISTANCE TO STOP**

To find the distance in which the brakes will stop a car, the following formula can be used:

$$D = \frac{WV^2 \times 0.0334}{CR},$$

in which C represents the coefficient of friction between tires and road surface, approx. 0.60 for rubber tires, and R the proportion of total weight carried by the wheels to which the brake is applied (this is assumed to be 0.6 of the whole weight). D is the distance in feet necessary for stopping.

ILLUSTRATIVE PROBLEM

Find the distance in which the brakes will act on an automobile equipped with good rubber tires travelling at a momentum of 10 miles per hour, if it weighs 2000 lbs.

$$D = \frac{2000 \times 100 \times 0.0334}{0.60 \times (.6 \times 2000)} = \frac{6680}{720} = 9.2.$$

Therefore the distance in which the brakes will act is 9.2 feet.

EXERCISES

In each of the following cases find the length in which the brakes will act:

	Weight	Miles per Hour		Weight	Miles per Hour
1.	2 ton	6	5.	1800 lbs.	45
2.	1200 lbs.	30	6.	3400 lbs.	25
3.	2600 lbs.	18	7.	2½ ton	32
4.	5 ton	12	8.	2800 lbs.	8

5. Find the distance in which the brakes will act on an automobile equipped with good rubber tires travelling at a momentum of 25 miles per hour if it weighs 2500 lbs.

BRAKES

PULL

To find the required pull P on the brake band, the following formula is used:

$$P = C.R. = \frac{WV^2 \times 0.0334}{D}.$$

ILLUSTRATIVE PROBLEM

Find the necessary braking pull for an automobile going 10 miles per hour and weighing 2000 lbs.

$$\begin{aligned} P &= \frac{W \quad V}{2000 \times (10)^2 \times 0.0334} = 720 \\ &= \frac{2000 \times 10 \times 10 \times 0.0334}{9.2} = \frac{6680}{9.2} = 720. \end{aligned}$$

Therefore the braking pull is 720 pounds. (9.2 is obtained from previous problem on page 97.)

EXERCISES

In each of the following cases find the number of pounds pull on the brake band:

	Weight	Miles per Hour		Weight	Miles per Hour
1.	2200 lbs.	40	7.	2700 lbs.	22
2.	2 ton	25	8.	3500 lbs.	15
3.	3400 lbs.	18	9.	$\frac{3}{4}$ ton	35
4.	$1\frac{1}{2}$ ton	12	10.	2400 lbs.	14
5.	1800 lbs.	30	11.	2 ton	5
6.	5 ton	8	12.	2800 lbs.	45

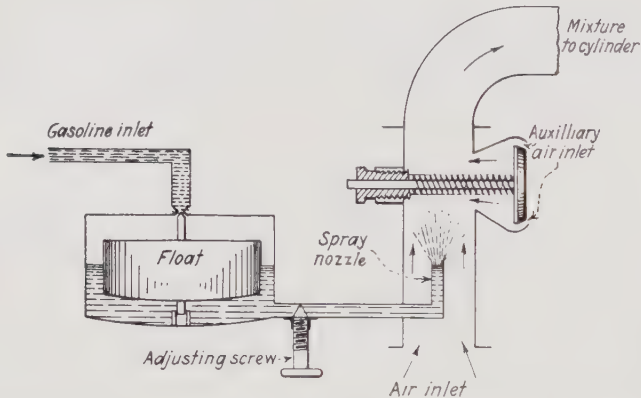
13. Find the necessary braking pull for an automobile going 26 miles per hour and weighing 3800 lbs.

CHAPTER VII

GASES

To obtain energy from gasoline it is necessary to convert the gasoline into vapor and then mix it with a volume of air before the mixture can be exploded in the cylinder. The exact amount of air to be mixed with a certain amount of vapor depends on the quality of the gasoline and other conditions.

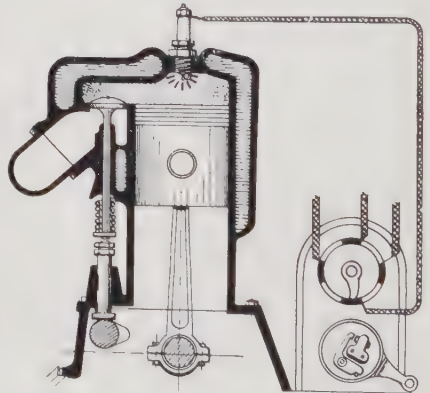
A device for mixing the air and gasoline is called a carburetor; a section of one is shown below.



The proportion commonly used is 14 parts of air to 1 part of gasoline. When the mixture is not correct, the engine will not deliver its full power.

The current of air passing through the gasoline takes small particles with it.

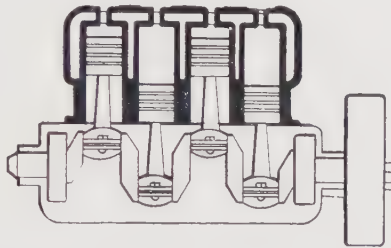
The piston of the engine on its suction stroke draws the mixture of gas and air into the closed end of the cylinder when the mixture is compressed and then exploded by the spark from the spark plug. The explosion is an almost instantaneous combustion, producing a very high temperature and a corresponding increase in pressure.



GASES

PISTON DISPLACEMENTS

The volume of gas displaced at one stroke of the piston is called piston displacement. When the piston is at top dead center, there is a certain volume in the combustion space above the piston. When the piston is at the bottom of the stroke, there is a greater volume above the piston. The difference between these spaces is called piston displacement.



This can be computed from the following formula:

$$P.D. = D^2 \times .7854 \times S \times N.$$

D = Diameter of piston multiplied by .7854 = Area of the base of a cylinder 1" in diameter.

S = Stroke in inches.

N = Number of cylinders.

ILLUSTRATIVE PROBLEM

Find the piston displacement for a 6-cylinder engine with a 3" bore and a 4" stroke.

The bore is the same dimension as the diameter of the piston.

$$\begin{aligned} P.D. &= D^2 \times .7854 \times S \times N \\ &= 3 \times 3 \times .7854 \times 4 \times 6 = 169.6. \end{aligned}$$

Therefore the piston displacement is 169.6 cu. in.

GASES

PISTON DISPLACEMENT

EXERCISES

1. Find the piston displacement for a 4-cylinder engine with a $3\frac{3}{4}$ " bore and a $4\frac{1}{4}$ " stroke.

In each of the following cases find the piston displacement:

	Cylinders	Bore	Stroke
2.	8	$3\frac{1}{2}$ "	$3\frac{5}{8}$ "
3.	4	$5\frac{1}{8}$ "	$4\frac{1}{4}$ "
4.	6	$4\frac{3}{4}$ "	$3\frac{7}{8}$ "
5.	8	$3\frac{1}{4}$ "	$5\frac{1}{4}$ "
6.	4	$4\frac{3}{8}$ "	$4\frac{7}{8}$ "

7. If the piston displacement of an engine with a $3\frac{3}{4}$ " stroke is 106 cu. in., find the diameter of the piston.

Find the missing specification in each of the following:

	Cylinders	Bore	Stroke	Displacement
8.	8	$3\frac{3}{16}$ "	$3\frac{1}{2}$ "	
9.	4		$4\frac{1}{8}$ "	194.6 cu. in.
10.		$2\frac{15}{16}$ "	$4\frac{7}{8}$ "	198.2 " "
11.	6	$3\frac{1}{2}$ "		245.3 " "
12.	12	$2\frac{7}{8}$ "	$5\frac{1}{8}$ "	
13.		$4\frac{11}{16}$ "	$5\frac{1}{2}$ "	379.6 " "
14.	4		$3\frac{1}{8}$ "	158.3 " "
15.	6		$4\frac{3}{8}$ "	361.5 " "

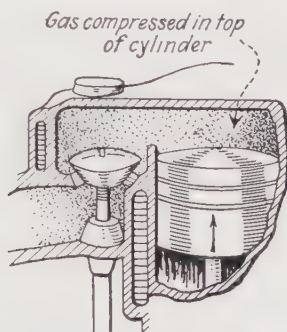
16. If an engine has a piston displacement of 648 cu. in., a 5" cylinder and a $5\frac{1}{2}$ " stroke, find the number of cylinders.

17. Which has the greater piston displacement, a four-cylinder engine with a 6" cylinder and a 3" stroke or a six-cylinder engine with a $4\frac{1}{8}$ " cylinder and a $4\frac{1}{4}$ " stroke?

GASES

COMPRESSION-VOLUMES

The pressure of the gas after being drawn into the cylinder and compressed in the combustion chamber varies with the quantity of gas drawn into the cylinder, speed of the piston, size of combustion chamber and the condition of the valves and piston rings.



The compression follows a rule called Boyle's Law which states: *The volume of a gas at constant temperature varies inversely as the pressure.* This means that, in a volume of gas or air subject to a certain pressure, if the pressure is doubled the volume will be reduced one-half. Expressed as a proportion:

$$P : P' = V' : V,$$

where P and P' are pressures and V and V' the corresponding volumes of a given quantity of gas kept at same fixed temperature.

As a gas mixture is compressed it becomes heated and the greater the pressure the greater the heat.

To keep a constant temperature, a cooling device must be used. The explosion pressure is commonly three to four times that of the compression. If the compression drops one-half, then the explosion pressure drops, but the loss is in more than direct proportion.

GASES

COMPRESSION-VOLUMES

ILLUSTRATIVE PROBLEM

If the mean effective pressure of a six-cylinder engine with a 3'' bore and 4'' stroke is 90 lbs. per sq. in., find the volume of the compressed mixture.

$$V : V' = P' : P,$$

where V = Volume of compressed mixture.

V' = Volume of cylinder (from formula on page 100).

P = Pressure of compressed mixture.

P' = Pressure of gas before compression—assumed to be 14.7 lbs., the same as atmospheric pressure.

$$V : 169.6 = 14.7 : 90,$$

$$V = \frac{169.6 \times 14.7}{90} = 27.71.$$

Therefore the compressed volume of mixture is 27.71 cu. in.

EXERCISES

1. Find the volume of the compressed mixture in a 4'' cylinder gas engine with a $3\frac{3}{4}$ '' bore and $4\frac{1}{4}$ '' stroke, when the compression pressure is 108 lbs.

Find the compressed volume of gas in each of the following:

	No. of Cylinders	Bore	Stroke	Compression Pressure
2.	6	$2\frac{1}{2}$ ''	4''	90 lbs.
3.	4	4''	4''	105 "
4.	4	5''	$4\frac{1}{4}$ ''	80 "
5.	6	$4\frac{1}{2}$ ''	$4\frac{5}{8}$ ''	95 "
6.	8	$4\frac{9}{16}$ ''	5''	115 "
7.	12	$2\frac{1}{2}$ ''	$5\frac{1}{2}$ ''	100 "

CHAPTER VIII

SPRINGS

In order to protect the occupants from vibration and also keep the machinery from being shaken to pieces it is necessary to equip automobiles with springs.

Elliptic springs are used in automobile design because this class of spring lends itself more readily to easy vibration as well as to better general design of the machine. There are four types in common use: Full elliptic, three quarter elliptic, half elliptic and cantilever.



Full Elliptic



Half Elliptic



Cantilever

Elliptic springs are used because it is possible to support a given load on a narrow-leaved elliptic spring where there would not be room for a helical spring.

Because ordinary steel cannot be used for automobile springs, various grades of high-carbon, nickel, chromium and vanadium steels must be obtained. On account of the high elastic limit, the various alloys made from vanadium steel appear to be the best for elliptic springs.

The weight of the vehicle determines the size and the strength of springs. If the springs are too weak, there will not be sufficient protection to the occupants and machinery; if they are too strong, they will not have enough resiliency. Breakage always occurs in the expansion that follows a heavy compression; therefore it is the rebound that breaks the spring.

SPRINGS

CARRYING CAPACITY

The usefulness of a spring depends largely on the length of structure between attached parts, the quality of the steel and the number of leaves.

To find P , the maximum carrying capacity of a full elliptic spring with all the leaves graduated, the following formula can be used:

$$P = \frac{2SNBH^2}{3L},$$

where P = maximum carrying capacity of the spring.

S = fiber stress assumed as 80,000 lbs. per sq. in. for steel.

N = one half the number of leaves in both parts of a full elliptic spring and total number of leaves in half elliptic spring

B = width of leaves.

H = thickness of leaves.

L = effective span.

ILLUSTRATIVE PROBLEM

Find the maximum carrying capacity of a full elliptic spring with 12 leaves 2'' wide, $\frac{1}{4}$ '' thick, when the effective span is 30''.

Using the above formula,

$$P = \frac{2 \times 80,000 \times 6 \times 2 \times 1 \times 1}{3 \times 30 \times 4 \times 4} = \frac{4000}{3} = 1333.3.$$

Therefore the safe load is 1300 lbs.

EXERCISES

In each of the following cases of full elliptic springs, find the maximum carrying capacity:

	Number of Leaves	Width	Thickness	Effective Span
1.	10	$2\frac{1}{4}$ ''	$\frac{5}{16}$ ''	32''
2.	12	$1\frac{3}{4}$ ''	$\frac{3}{16}$ ''	36''
3.	2	2''	$\frac{7}{32}$ ''	28''

SPRINGS

ELASTICITY

When an automobile goes over a ditch or rough road, the springs are subjected to tension, compression, and other stresses within the material. If the stress is not too great, the springs return to their original shape and dimensions when a smooth road is reached. This property which enables a material to return to its original shape and dimensions is called its elasticity.

The deflection of an elliptic spring under load P is found by using the following formula:

$$F = \frac{SL^2}{2EH},$$

where S , L and H are obtained from page 105,
 F = deflection of spring under load P ,
 E = modulus of elasticity = 25,400,000.
 Substituting 25,400,000 in the equation, we have

$$F = \frac{0.0016L^2}{H}.$$

Using the figures given in the illustrative problem on page 105 for L and H , we have

$$F = \frac{0.0016 \times (30)^2}{\frac{1}{4}} \quad \text{or} \quad 0.0016 \times 30 \times 30 \times 4 = 5.76.$$

Therefore the deflection is 5.76".

In each of the following cases find the deflection:

	Thickness of Leaves	Effective Span	Answer
1.	$\frac{3}{32}$ "	28"	
2.	$\frac{5}{16}$ "	32"	
3.	$\frac{7}{32}$ "	30"	

CHAPTER IX

GEARS

Gears of various types are used on an automobile to transmit power from the engine to the rear axle and to drive the cam shaft and generator shaft. Some of the common types are shown below.

A gear is a wheel with projections called teeth on its circumference. The smaller of two gears is called a pinion.

While it is possible for gear teeth to have many shapes, there are but two systems in general use, the involute or single curve form of tooth and the cycloidal or double curve form. The involute form is most commonly used.

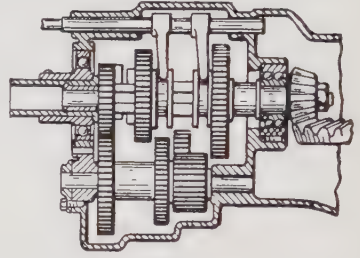


Fig. 1

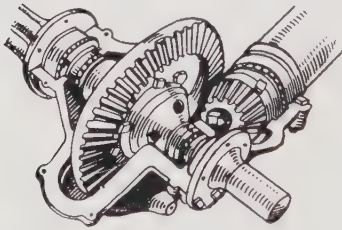


Fig. 2

A spur gear (Fig. 1) is a toothed wheel in which the teeth are cut parallel to the axis and at right angles to the sides. These gears transmit power to parallel shafts.

Bevel gears (Fig. 2) are gears whose teeth cut on an angle to the axis and connect shafts that are not parallel. Usually the shafts are at right angles.

Spiral gears (Fig. 3) are gears in which the teeth are wound spirally around the axis. The shafts may be parallel or at any angle.

Worm gearing (Fig. 4) is used when a large reduction in speed is necessary. The shafts are usually at right angles to each other.

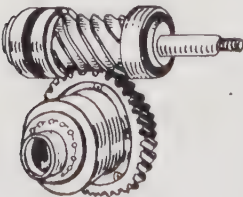


Fig. 4

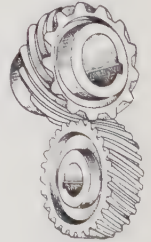


Fig. 3

The automobile makes use of all these different kinds of gears. In the transmission case we find spur gears, on the propeller shaft and differential spider we find bevel gears, a worm and worm wheel is found on the steering gear while spiral teeth are sometimes used on the cam shaft gear.

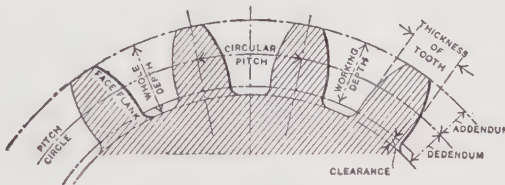
GEARS

PITCH

In order that gears of different diameters may mesh, i.e., run together, their teeth must all be the same size. There are two systems employed to make this possible: (1) Diametral Pitch, (2) Circular Pitch.

(1) Diametral pitch is the ratio of the number of teeth per unit of the pitch diameter of gear. Thus if there are 24 teeth on a gear with a pitch diameter of 6", the diametral pitch of the gear is $24/6$ or 4.

(2) Circular pitch is the distance between the centers of two adjacent teeth measured on the pitch circle.



By using a simple formula it is possible to find the circular pitch corresponding to the diametral pitch and vice versa.

$$\text{Circular pitch} = \frac{\pi}{\text{diametral pitch}},$$

$$\text{Diametral pitch} = \frac{\pi}{\text{circular pitch}}.$$

Note: When the word "pitch" is used alone it always refers to the diametral pitch. The difference in the use of the term "pitch" as applied to gears and to screw threads should be noted. Thus, we speak of a screw with 8 threads to the inch as a screw of $\frac{1}{8}$ -inch pitch, while a gear that has 8 teeth to each inch of the pitch diameter is called an 8-pitch gear.

GEARS

PITCH

ILLUSTRATIVE PROBLEMS

- (a) Find the circular pitch of a gear when the pitch is 6.

$$\text{Circular pitch} = \frac{\pi}{\text{diametral pitch}} = \frac{3.1416}{6} = 0.5236''.$$

- (b) Find the diametral pitch of a gear when the circular pitch is 1.0472.

$$\text{Diametral pitch} = \frac{\pi}{\text{circular pitch}} = \frac{3.1416}{1.0472} = 3.$$

EXERCISES

1. What is the circular pitch of a gear which has a pitch of 42?
2. Find the diametral pitch of a gear when the circular pitch is 2.5133.

Find the circular pitch of a gear when the diametral pitch in each case is as follows:

- | | | | | | |
|--------------------|--------------------|---------------------|---------|---------|---------|
| 3. $\frac{1}{2}$. | 4. $\frac{3}{4}$. | 5. $2\frac{1}{2}$. | 6. 5. | 7. 11. | 8. 14. |
| 9. 22. | 10. 28. | 11. 36. | 12. 44. | 13. 48. | 14. 50. |

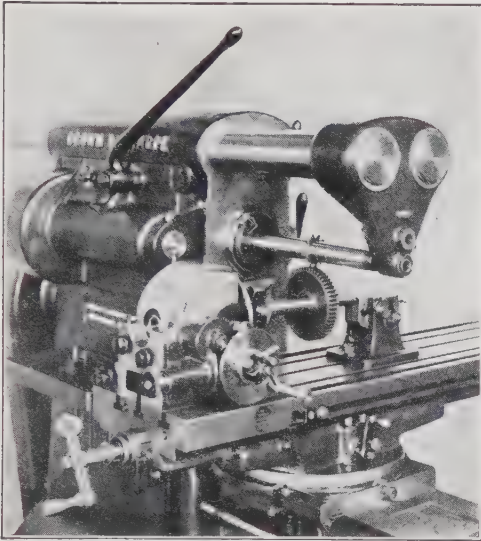
Find the diametral pitch of a gear when the circular pitch in each case is as follows:

- | | | | | |
|-----------------------|------------------------|---------------|------------------------|---------------|
| 15. 0.654''. | 16. 4''. | 17. 0.0785''. | 18. $1\frac{3}{4}$ ''. | 19. 0.1745''. |
| 20. $\frac{7}{8}$ ''. | 21. $\frac{1}{16}$ ''. | 22. 0.2618''. | 23. 0.8976''. | 24. 1.424''. |
| 25. 1.7952''. | 26. $1\frac{5}{8}$ ''. | | | |

GEARS

GEAR CUTTERS

Although an auto mechanic is seldom called upon to cut a gear, sometimes in an emergency a knowledge of the fundamentals of gears will be of service.

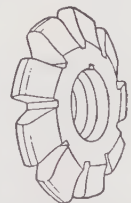


Cutting a spur gear on a milling machine.

In production plants, gears are cut on automatic gear-cutting machines. The teeth of single gears can be cut on a milling machine or on a lathe if there is no milling machine in the shop. When cut on a lathe the gear is held by a special fixture on the cross slide, the gear cutter being placed on an arbor between the centers. On both milling machine and lathe the center line on the cutter teeth must be central

with the axis of the gear blank which is held on an arbor between centers.

It is important that the gear cutter have the proper pitch and the correct number be selected. If with these cutters the proper depth and correct indexing are used, the thickness of tooth on the pitch line will be correct. The table below aids in the selection of the cutter.



Involute gear cutter

Number of Cutter	Number of Teeth	Number of Cutter	Number of Teeth
1	135 to rack	5	21 to 25
2	55 to 134	6	17 to 20
3	35 to 54	7	14 to 16
4	26 to 34	8	12 to 13

GEARS

In order to cut a gear and then check its measurements, the depth, thickness of tooth on pitch line, and outside diameter must be known. These elements can be determined by the following formula:

$$(a) \quad \text{Total depth of tooth} = \frac{2.157}{\text{diametral pitch}}.$$

ILLUSTRATIVE PROBLEM

Find the total depth of a 10 diametral pitch gear.

$$D = \frac{2.157}{10} = .2157.$$

Therefore the total depth of a 10-pitch gear is 0.2157".

(b) The Thickness of a Gear Tooth.

$$\text{Thickness of tooth} = \frac{\text{circular pitch}}{2} \quad \text{or} \quad \frac{1.57}{\text{diametral pitch}}.$$

ILLUSTRATIVE PROBLEM

Find the thickness of tooth on a 10 diametral pitch gear.

$$\text{circular pitch} = \frac{3.1416}{10} = 0.31416,$$

$$T = \frac{0.31416}{2} = 0.157 \quad \text{or} \quad \frac{1.57}{10} = 0.157.$$

Therefore the thickness of a tooth on the pitch line of a 10-pitch gear is 0.157".

(c) The Outside Diameter.

$$\text{Outside diameter} = \frac{\text{number of teeth} \times 2}{\text{diametral pitch}}.$$

ILLUSTRATIVE PROBLEM

What should be the outside diameter of a gear blank for 48 teeth 10 diametral pitch.

$$O.D. = \frac{48 + 2}{10} = 5.$$

Therefore the outside diameter should be 5".

GEARS

EXERCISES

1. Find the thickness of tooth on an 18-pitch gear.
2. Find the total depth of a 16-pitch gear.
3. What should be the outside diameter of a gear blank for 24 teeth 18 pitch?
4. Find the total depth of a gear having a pitch of $1\frac{3}{4}$ ".
5. What is the outside diameter of a gear blank for a gear which is to have 122 teeth and the circular pitch of which is to be .0785"?
6. Find the outside diameter of a gear blank for 78 teeth, 12 pitch.
7. Calculate the thickness of tooth on a gear of 24 pitch.
8. What should be the total depth on a gear of $\frac{1}{2}$ pitch?
9. Find the thickness of tooth on a gear of 0.2244" circular pitch.
10. Find the outside diameter of a gear blank for 17 teeth and 11 diametral pitch.
11. Find the total depth of a 9-pitch gear.
12. Does the number of teeth on a gear with the same pitch make any difference in the thickness of tooth?

The word "pitch" when used alone always refers to the diametral pitch.

13. What should be the outside diameter of a gear blank for 46 teeth and 16 pitch?
14. Find the circular pitch of a gear whose teeth on the pitch circle measure 1.75".
15. What is the diametral pitch of a gear whose teeth on the pitch circle measure 0.2244"?

GEARS

CENTER DISTANCE

In finding the center distance D_c between two spur gears in mesh, the following formula may be used:

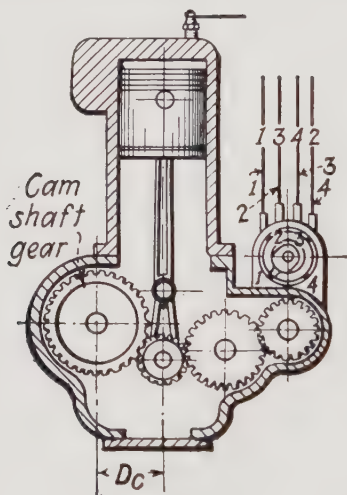
$$\text{Distance between centers} = \frac{\text{sum of teeth on both gears}}{2 \times \text{diametral pitch}}.$$

ILLUSTRATIVE PROBLEM

If the cam shaft gear has 46 teeth and the crankshaft gear has 26 teeth, what is the center distance when the diametral pitch is 18?

$$D_c = \frac{26 + 46}{2 \times 18} = \frac{72}{36} = 2.$$

Therefore the distance between the centers of the two gears is 2".



EXERCISES

1. Two gears in mesh have 32 teeth and 108 teeth respectively. If they are 11 pitch, what is the distance between their centers?
2. What is the center distance of two gears in mesh of 14 pitch if their numbers of teeth are respectively 26 teeth and 72 teeth?
3. Two gears in mesh have 78 and 136 teeth respectively. If their pitch is 6, what is the center distance?

GEARS

EXERCISES

1. What is a spur gear?
2. Where are spur gears used on an automobile?
3. How does circular pitch differ from diametral pitch?
4. Find the pitch of a gear in which the circular pitch is equal to 6.2832".
5. Find the whole depth of a tooth on a spur gear which has a circular pitch of 0.1745".
6. If a gear has 79 teeth and the pitch is 9, what is the outside diameter?
7. What is the pitch of a gear which has a circular pitch of 0.7854"?
8. If two 6-pitch gears in mesh have 182 teeth and 96 teeth respectively, what is the center distance?
9. What number would be obtained in every case if the pitch were multiplied by the circular pitch?
10. The diametral pitch of a gear is 17. Find the circular pitch.
11. What is the center distance of two gears in mesh having 126 teeth and 18 teeth respectively with a pitch of 14?
12. Where are bevel gears used on an automobile? Spiral gear? Worm gearing?
13. Two gears in mesh have 36 teeth and 24 teeth respectively. If their pitch is 16, what is the center distance?
14. If the outside diameter of a gear is 18" and the pitch is 6, what is the number of teeth?
15. What should be the diameter of a gear blank which is to have cut on it 46 teeth when the circular pitch is to be 0.1309"?

TABLES FOR REFERENCE

TABLES OF MEASURES

LENGTH

12 inches (in. or ") = 1 foot (ft. or ')

3 feet = 1 yard (yd.)

$5\frac{1}{2}$ yards, or $16\frac{1}{2}$ feet = 1 rod (rd.)

320 rods, or 5,280 feet = 1 mile (mi.)

SQUARE MEASURE

144 square inches (sq. in.) = 1 square foot (sq. ft.)

9 square feet = 1 square yard (sq. yd.)

$30\frac{1}{4}$ square yards = 1 square rod (sq. rd.)

160 square rods = 1 acre (A.)

CUBIC MEASURE

1,728 cubic inches (cu. in.) = 1 cubic foot (cu. ft.)

27 cubic feet = 1 cubic yard (cu. yd.)

128 cubic feet = 1 cord (cd.)

WEIGHT

16 ounces (oz.) = 1 pound (lb.)

2,000 pounds = 1 ton (T.)

LIQUID MEASURE

4 gills (gi.) = 1 pint (pt.)

2 pints = 1 quart (qt.)

4 quarts = 1 gallon (gal.)

ANGLES AND ARCS

60 seconds (") = 1 minute (')

60 minutes = 1 degree (°)

90 degrees = 1 right angle

360 degrees = 1 circumference

DECIMAL EQUIVALENTS OF COMMON FRACTIONS

Fraction				Decimal	Fraction				Decimal
$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	0.015625	$\frac{9}{16}$	$\frac{17}{32}$	$\frac{33}{64}$	0.515625	
			$\frac{3}{64}$	.03125			$\frac{35}{64}$	.53125	
			$\frac{5}{64}$	.046875			$\frac{37}{64}$	.546875	
			$\frac{7}{64}$	.0625			$\frac{39}{64}$	.5625	
				.078125				.578125	
	$\frac{3}{16}$	$\frac{3}{32}$		.09375	$\frac{11}{16}$	$\frac{23}{32}$	$\frac{41}{64}$	.60375	
				.109375			$\frac{43}{64}$	.625	
				.125				.640625	
			$\frac{9}{64}$	.140625			$\frac{45}{64}$	.65625	
			$\frac{11}{64}$	.15625			$\frac{47}{64}$	.671875	
$\frac{1}{4}$	$\frac{5}{16}$	$\frac{7}{32}$	$\frac{13}{64}$	.171875	$\frac{3}{4}$	$\frac{25}{32}$	$\frac{49}{64}$	.6875	
			$\frac{15}{64}$	.1875			$\frac{51}{64}$	.703125	
				.203125			$\frac{53}{64}$	.71875	
				.21875			$\frac{55}{64}$	.734375	
				.234375				.75	
	$\frac{7}{16}$	$\frac{9}{32}$	$\frac{17}{64}$	.25	$\frac{5}{8}$	$\frac{27}{32}$	$\frac{57}{64}$	.765625	
			$\frac{19}{64}$	.265625			$\frac{59}{64}$	.78125	
			$\frac{21}{64}$	.28125			$\frac{61}{64}$	.796875	
			$\frac{23}{64}$	.296875			$\frac{63}{64}$	.8125	
				.3125				.828125	
$\frac{3}{8}$	$\frac{13}{16}$	$\frac{11}{32}$	$\frac{25}{64}$	.328125	$\frac{7}{8}$	$\frac{29}{32}$	$\frac{65}{64}$	.84375	
			$\frac{27}{64}$	.34375			$\frac{67}{64}$	.859375	
			$\frac{29}{64}$	.359375			$\frac{69}{64}$	.875	
				.375			$\frac{71}{64}$	.890625	
			$\frac{31}{64}$	.390625			$\frac{73}{64}$	.90625	
	$\frac{15}{16}$	$\frac{13}{32}$	$\frac{33}{64}$	.40625	1	$\frac{31}{32}$	$\frac{75}{64}$	.921875	
			$\frac{35}{64}$	.421875			$\frac{77}{64}$	.9375	
			$\frac{37}{64}$	.4375			$\frac{79}{64}$	.953125	
			$\frac{39}{64}$	.453125			$\frac{81}{64}$	.96875	
			$\frac{41}{64}$	.46875			$\frac{83}{64}$	.984375	
$\frac{1}{2}$	$\frac{31}{32}$	$\frac{31}{64}$	$\frac{43}{64}$	.484375					
				.5					1.

THE METRIC SYSTEM OF MEASUREMENT

MEASURES OF LENGTH

1 Millimeter (mm.) =	.03937079 inch, or about 1/25 inch
10 Millimeters = 1 Centimeter (cm.) =	0.3937079 "
10 Centimeters = 1 Decimeter (dm.) =	3.937079 "
10 Decimeters = 1 Meter (m.) = 39.37079 inches, 3.2808992 feet, or 1.09361 yards	
10 Meters = 1 Decameter (Dm.) =	32.808992 feet
10 Decameters = 1 Hectometer (Hm.) =	19.927817 rods
10 Hectometers = 1 Kilometer (Km.) = 1093.61 yards, or 0.6213824 mile	
10 Kilometers = 1 Myriameter (Mm.) =	6.213824 miles
1 inch = 2.54 cm., 1 foot = 0.3048 m., 1 yard = 0.9144 m., 1 rod = 0.5029 Dm., 1 mile = 1.6093 Km.	

MEASURES OF WEIGHT

1 Gramme (g.) = 15.4324874 gr. Troy, or 0.03215 oz. Troy, or 0.03527398 oz. avoird.	
10 Grammes = 1 Decagramme (Dg.) =	0.3527398 oz. avoird.
10 Decagrammes = 1 Hectogramme (Hg.) =	3.527398 " "
10 Hectogrammes = 1 Kilogramme (Kg.) =	2.20462125 lbs.
1000 Kilogrammes = 1 Tonne (T.) = 2204.62125 lbs., or 1.1023 tons of 2000 lbs., or 0.9842 ton of 2240 lbs., or 19.68 cwts.	
1 grain = 0.0648 g., 1 oz. avoird. = 28.35 g., 1 lb. = 0.4536 Kg., 1 ton 2000 lbs. = 0.9072 T., 1 ton 2240 lbs. = 1.016 T., or 1016 Kg.	

MEASURES OF CAPACITY

1 Liter (l.) = 1 cubic decimeter = 61.0270515 cu. in., or 0.03531 cu. ft., or 1.0567 liquid qts., or 0.908 dry qt., or 0.26417 Amer. gal.	
10 Liters = 1 Decaliter (Dl.) = 2.6417 gal., or 1.135 pks.	
10 Decaliters = 1 Hectoliter (Hl.) = 2.8375 bu.	
10 Hectoliters = 1 Kiloliter (Kl.) = 61027.0515 cu. in., or 28.375 bu.	
1 cu. ft. = 28.317 l., 1 gallon Amer. = 3.785 l., 1 gallon Brit. = 4.543 l.	

TABLE OF DECIMAL EQUIVALENTS OF MILLIMETERS AND FRACTIONS OF MILLIMETERS

1/100 mm. = .0003937 inch

mm.	inches	mm.	inches	mm.	inches
1/50 =	.00079	26/50 =	.02047	2	.07874
2/50 =	.00157	27/50 =	.02126	3	.11811
3/50 =	.00236	28/50 =	.02205	4	.15748
4/50 =	.00315	29/50 =	.02283	5	.19685
5/50 =	.00394	30/50 =	.02362	6	.23622
6/50 =	.00472	31/50 =	.02441	7	.27559
7/50 =	.00551	32/50 =	.02520	8	.31496
8/50 =	.00630	33/50 =	.02598	9	.35433
9/50 =	.00709	34/50 =	.02677	10	.39370
10/50 =	.00787	35/50 =	.02756	11	.43307
11/50 =	.00866	36/50 =	.02835	12	.47244
12/50 =	.00945	37/50 =	.02913	13	.51181
13/50 =	.01024	38/50 =	.02992	14	.55118
14/50 =	.01102	39/50 =	.03071	15	.59055
15/50 =	.01181	40/50 =	.03150	16	.62992
16/50 =	.01260	41/50 =	.03228	17	.66929
17/50 =	.01339	42/50 =	.03307	18	.70866
18/50 =	.01417	43/50 =	.03386	19	.74803
19/50 =	.01496	44/50 =	.03465	20	.78740
20/50 =	.01575	45/50 =	.03543	21	.82677
21/50 =	.01654	46/50 =	.03622	22	.86614
22/50 =	.01732	47/50 =	.03701	23	.90551
23/50 =	.01811	48/50 =	.03780	24	.94488
24/50 =	.01890	49/50 =	.03858	25	.98425
25/50 =	.01969	1	.03937	26	1.02362

10 mm. = 1 centimeter = 0.3937 inch

10 cm. = 1 decimeter = 3.937 inches

10 dm. = 1 meter = 39.37 inches

25.4 mm. = 1 English inch.

SIZES OF TWIST DRILLS WITH DECIMAL EQUIVALENTS

Size	Decimal Equivalent	Size	Decimal Equivalent	Size	Decimal Equivalent	Size	Decimal Equivalent
$\frac{1}{2}''$	.5000''	$\frac{1}{4}''$	.2500''	#26	.01470''	#56	.00465''
$\frac{31}{64}''$	.4844	E	.2500	#27	.1440	#57	.0430
$\frac{15}{32}''$	.4688	D	.2460	$\frac{9}{64}''$	.1406	#58	.0420
$\frac{29}{64}''$	.4531	C	.2420	#28	.1405	#59	.0410
$\frac{7}{16}''$	.4375	B	.2380	#29	.1360	#60	.0400
$\frac{27}{64}''$	.4219	$\frac{15}{64}''$	.2344	#30	.1285	#60 $\frac{1}{2}$	.0390
Z	.4130	A	.2340	$\frac{1}{8}''$	.1250	#61	.0380
$\frac{13}{32}''$	.4063	#1	.2280	#31	.1200	#62	.0370
Y	.4040	#2	.2210	#32	.1160	#63	.0360
X	.3970	$\frac{7}{32}''$	.2188	#33	.1130	#64	.0350
$\frac{25}{64}''$	.3906	#3	.2130	#34	.1110	#65	.0330
W	.3860	#4	.2090	#35	.1100	#66	.0320
V	.3770	#5	.2055	$\frac{7}{64}''$	.1094	$\frac{1}{32}''$	.0313
$\frac{3}{8}''$	.3750	#6	.2040	#36	.1065	#67	.0310
U	.3680	$\frac{13}{64}''$	.2031	#37	.1040	#68	.0300
$\frac{23}{64}''$	.3594	#7	.2010	#38	.1015	#68 $\frac{1}{2}$	.0295
T	.3580	#8	.1990	#39	.0995	#69	.0290
S	.3480	#9	.1960	#40	.0980	#69 $\frac{1}{2}$	.0280
$\frac{11}{32}''$	.3438	#10	.1935	#41	.0960	#70	.0270
R	.3390	#11	.1910	$\frac{3}{32}''$	.0938	#71	.0260
Q	.3320	#12	.1890	#42	.0935	#71 $\frac{1}{2}$	.0250
$\frac{21}{64}''$	.3281	$\frac{3}{16}''$	.1875	#43	.0890	#72	.0240
P	.3230	#13	.1850	#44	.0860	#73	.0230
O	.3160	#14	.1820	#45	.0820	#73 $\frac{1}{2}$	.0225
$\frac{5}{16}''$	.3125	#15	.1800	#46	.0810	#74	.0220
N	.3020	#16	.1770	#47	.0785	#74 $\frac{1}{2}$	.0210
$\frac{19}{64}''$	.2969	#17	.1730	$\frac{5}{64}''$	.0781	#75	.0200
M	.2950	$\frac{11}{64}''$	.1719	#48	.0760	#76	.0180
L	.2900	#18	.1695	#49	.0730	#77	.0160
$\frac{9}{32}''$	.2813	#19	.1660	#50	.0700	$\frac{1}{64}''$	.0156
K	.2810	#20	.1610	#51	.0670	#78	.0150
J	.2770	#21	.1590	#52	.0635	#78 $\frac{1}{2}$	.0145
I	.2720	#22	.1570	$\frac{1}{16}''$	.0625	#79	.0140
H	.2660	$\frac{5}{32}''$	.1563	#53	.0595	#79 $\frac{1}{2}$	.0135
$\frac{17}{64}''$	.2656	#23	.1540	#54	.0550	#80	.0130
G	.2610	#24	.1520	#55	.0520	...	
F	.2570	#25	.1495	$\frac{3}{64}''$	.0469	...	

U. S. S.-THREAD BOLTS AND NUTS

OUTSIDE DIAMETER	THREADS TO 1"	ROOT DIAMETER	DIAMETER OF TAP DRILL	AREA IN SQUARE INCHES		DIMENSIONS OF NUTS AND BOLT HEADS				
				Of Bolt	At Root of Thread					
1/4"	20	0.185"	1/16"	0.049	0.026	1/8"	0.578"	0.707"	1/4"	1/4"
1/8"	18	0.240	1/16"	0.076	0.045	1/8"	0.686	0.840	1/4"	1/4"
3/16"	16	0.294	1/16"	0.110	0.068	1/8"	0.794	0.972	1/4"	1/4"
1/4"	14	0.345	1/16"	0.150	0.093	1/8"	0.902	1.105	1/4"	1/4"
5/16"	13	0.400	1/16"	0.196	0.126	1/8"	1.011	1.237	1/4"	1/4"
3/8"	12	0.454	1/16"	0.248	0.162	1/8"	1.119	1.370	1/4"	1/4"
7/16"	11	0.507	1/16"	0.307	0.202	1/8"	1.227	1.502	1/4"	1/4"
1/2"	10	0.620	1/16"	0.442	0.302	1/8"	1.444	1.768	1/4"	1/4"
5/8"	9	0.731	1/16"	0.601	0.419	1/8"	1.660	2.033	1/4"	1/4"
3/4"	8	0.838	1/16"	0.785	0.551	1/8"	1.877	2.298	1/4"	1/4"
7/8"	7	0.939	1/16"	0.994	0.694	1/8"	2.093	2.563	1/4"	1/4"
1"	7	1.064	1/16"	1.227	0.893	2	2.310	2.828	1/4"	1/4"
1 1/8"	6	1.158	1/16"	1.485	1.057	2 3/16"	2.527	3.093	1/4"	1 3/8"
1 1/4"	6	1.283	1/16"	1.767	1.295	2 3/8"	2.743	3.358	1/4"	1 3/8"
1 1/2"	5 1/2	1.389	1/16"	2.074	1.515	2 9/16"	2.960	3.623	1/4"	1 3/8"
1 3/4"	5	1.490	1/16"	2.405	1.746	2 5/8"	3.176	3.889	1/4"	1 3/8"
2"	5	1.615	1/16"	2.761	2.051	2 11/16"	3.393	4.154	1/4"	1 3/8"
2 1/8"	4 1/2	1.711	1/16"	3.142	2.302	3 1/8"	3.609	4.419	2	1 9/16"
2 1/4"	4 1/2	1.961	2	3.976	3.023	3 1/2"	4.043	4.949	2 1/4"	1 9/16"
2 1/2"	4	2.175	2	4.909	3.719	3 3/4"	4.476	5.479	2 1/2"	1 9/16"
2 3/4"	4	2.425	2	5.940	4.620	4 1/4"	4.909	6.010	2 3/4"	2 1/8"
3"	3 1/2	2.629	2	7.069	5.428	4 3/8"	5.342	6.540	3	2 1/8"
3 1/4"	3 1/2	2.879	2 1/16"	8.296	6.510	5	5.775	7.070	3 1/4"	2 3/8"
3 1/2"	3 1/4	3.100	3 1/16"	9.621	7.548	5 3/8"	6.208	7.600	3 1/2"	2 3/8"
3 3/4"	3	3.317	3	11.045	8.641	5 3/4"	6.641	8.131	3 3/4"	2 3/8"
4"	3	3.567	3	12.566	9.963	6 1/8"	7.074	8.661	4	3 1/8"
4 1/4"	2 7/8	3.798	3 3/8"	14.186	11.340	6 1/2"	7.508	9.191	4 1/4"	3 1/8"
4 1/2"	2 7/8	4.028	4	15.904	12.750	6 7/8"	7.941	9.721	4 1/2"	3 1/8"
4 3/4"	2 5/8	4.255	4 1/8"	17.721	14.215	7 1/4"	8.374	10.252	4 3/4"	3 1/8"
5"	2 1/2	4.480	4 9/16"	19.635	15.760	7 3/8"	8.807	10.782	5	3 1/8"
5 1/4"	2 1/2	4.730	4 11/16"	21.648	17.570	8	9.240	11.312	5 1/4"	4
5 1/2"	2 1/2	4.953	5 1/16"	23.758	19.260	8 3/8"	9.673	11.842	5 1/2"	4 3/16"
5 3/4"	2 1/2	5.203	5 1/8"	25.967	21.250	8 1/2"	10.106	12.373	5 3/4"	4 3/16"
6"	2 1/4	5.423	5 1/2"	28.274	23.090	9 1/8"	10.539	12.903	6	4 9/16"

TAP-DRILL SIZES 75% DEPTH OF THREAD

S.A.E. STANDARD

Thread Diameter	Threads to Inch	Diameter of Drill	Thread Diameter	Threads to Inch	Diameter of Drill
$\frac{1}{4}$ "	28	$\frac{1}{8}$ 3	$\frac{3}{4}$ "	16	$\frac{11}{16}$ "
$\frac{5}{16}$ "	24	I	$\frac{7}{8}$ "	18	$\frac{5}{8}$ "
$\frac{3}{8}$ "	24	Q	$\frac{7}{8}$ "	14	$\frac{13}{16}$ "
$\frac{7}{16}$ "	20	$\frac{25}{64}$ "	1"	14	$\frac{15}{16}$ "
$\frac{1}{2}$ "	20	$\frac{29}{64}$ "	$\frac{11}{16}$ "	12	$\frac{13}{16}$ "
$\frac{9}{16}$ "	18	$\frac{64}{32}$ "	$\frac{11}{16}$ "	12	$\frac{11}{16}$ "
$\frac{5}{8}$ "	18	$\frac{64}{32}$ "	$\frac{13}{16}$ "	12	$\frac{19}{64}$ "
$\frac{11}{16}$ "	16	$\frac{64}{32}$ "	1"	12	$\frac{27}{64}$ "
		$\frac{5}{8}$ "			

TAP DRILLS FOR BRIGGS PIPE THREADS

Nominal Size	Threads to 1"	Diameter of Drill	Nominal Size	Threads to 1"	Diameter of Drill
$\frac{1}{8}$ "	27	.0328"	$\frac{1}{2}$ "	11 $\frac{1}{2}$	1.719"
$\frac{1}{4}$ "	18	.453"	2"	11 $\frac{1}{2}$	2.188"
$\frac{3}{8}$ "	18	.594"	$2\frac{1}{2}$ "	8	2.688"
$\frac{1}{2}$ "	14	.719"	3"	8	3.313"
$\frac{3}{4}$ "	14	.938"	$3\frac{1}{2}$ "	8	3.813"
1"	11 $\frac{1}{2}$	1.188"	4"	8	4.313"
$1\frac{1}{4}$ "	11 $\frac{1}{2}$	1.469"	$4\frac{1}{2}$ "	8	4.813"

The diameter of drill allows for reaming the hole before tapping.

TAP DRILLS FOR U. S. S. THREADS

Thread Diameter	Threads to 1"	Diameter of Drill	Thread Diameter	Threads to 1"	Diameter of Drill
$\frac{1}{4}$ "	20	0.191"	1"	8	0.854"
$\frac{5}{16}$ "	18	.248"	$\frac{11}{16}$ "	7	0.957"
$\frac{3}{8}$ "	16	.302"	$\frac{13}{16}$ "	7	1.082"
$\frac{7}{16}$ "	14	.354"	$\frac{15}{16}$ "	6	1.179"
$\frac{1}{2}$ "	13	.409"	1"	6	1.304"
$\frac{9}{16}$ "	12	.465"	$\frac{11}{16}$ "	5 $\frac{1}{2}$	1.412"
$\frac{5}{8}$ "	11	.518"	$\frac{13}{16}$ "	5	1.515"
$\frac{3}{4}$ "	10	.632"	$\frac{7}{8}$ "	5	1.640"
$\frac{7}{8}$ "	9	.745"	2"	4 $\frac{1}{2}$	1.739"

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